

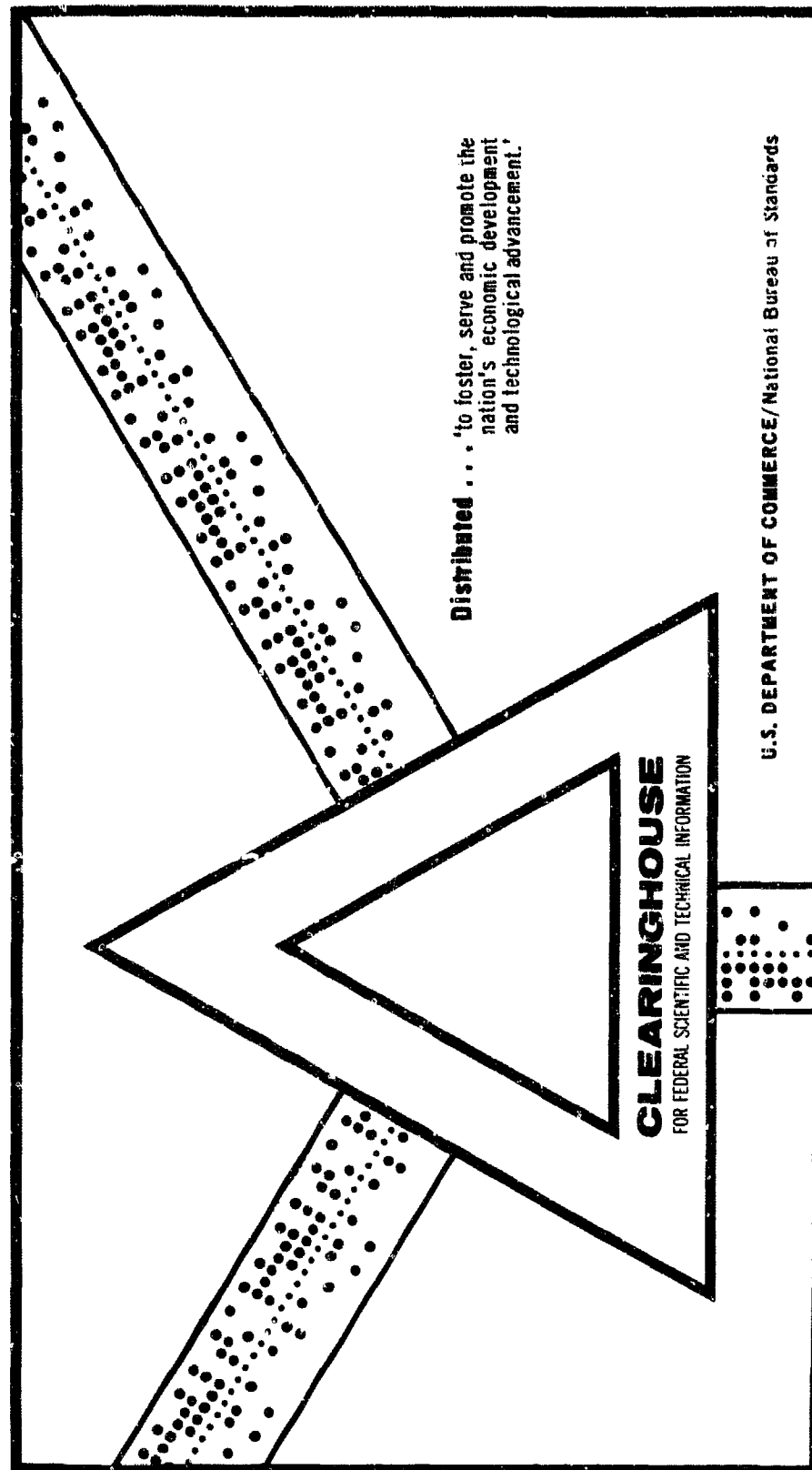
AD 697 020

A SELECTED ANNOTATED BIBLIOGRAPHY ON LIGHTNING (1964-1969)

Alvin L. Smith, Jr., et al

Environmental Technical Applications Center (Air Force)  
Washington, D. C.

November 1969



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# ENVIRONMENTAL *Technical Applications Center*

AD 697020

ETAC

TECHNICAL NOTE

69-8

A

## SELECTED ANNOTATED BIBLIOGRAPHY ON LIGHTNING

By

Alvin L. Smith, Jr.

and

Dennis L. Boyer

November 1969



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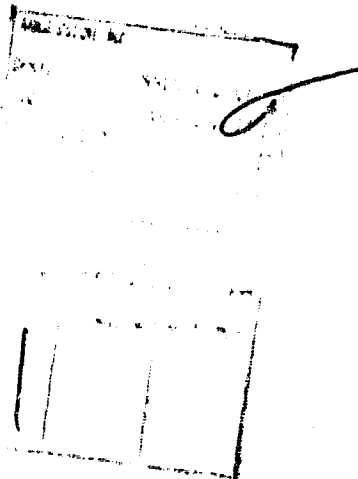
### Purpose

USAF ETAC Technical Notes are published by the USAF Environmental Technical Applications Center to disseminate aerospace sciences information to units of the Air Weather Service. Subject matter contained in these Technical Notes, while pertinent, is not deemed appropriate for publication as Air Weather Service Technical Reports which are confined to those studies, reports, techniques, etc., of a more permanent and specific nature. Technical Notes include such material as wing seminar listings, bibliographies, special data compilations, climatic studies, and certain USAF ETAC project reports which may be of special interest to units of the AWS organization. This series is published under the provisions of AFR 6-1 and AWSR 80-2, as amended.

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### Preface

One of the primary functions of the Technical Information Section, USAF Environmental Technical Applications Center (ETAC) is to locate climatological reference material requested by the various governmental agencies and those civilian organizations completing government contracts. The requests are generally initiated to aid in the solution of specific problems. However, many of these bibliographies represent a substantial listing of climatic sources which, having been assembled, could prove very beneficial to other researchers with similar interests in subject matter or area of coverage. It is with this in mind that USAF ETAC publishes certain reference listings such as this bibliography. It is believed that, by the publication and distribution of these consolidated reference lists, much of the time-consuming reference-searching of the climatologist can be eliminated.

## INTRODUCTION

This annotated bibliography was prepared as a by-product of the routine reference-searching that characterizes the main workload of the USAF ETAC, Technical Information Section. Many abstracts were taken from the publications themselves and credit is given to the author. Others were reprinted from the "Meteorological & Geostrophysical Abstracts" of the American Meteorological Society, "Scientific and Technical Aerospace Reports" of NASA, "Technical Abstract Bulletin" of the Defense Documentation Center, or "U.S. Government Research & Development Reports" of the Clearinghouse. Still others were written by persons within USAF ETAC. Identification of the personnel afforded credit for abstracts used in this bibliography is shown below:

<u>Initials</u>	<u>Identification</u>	<u>Initials</u>	<u>Identification</u>
DLB	Dennis L. Boyer	ES	Evelyn Sinha
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RB	Ronald Baker	JPD	J. P. Dickson
VJC	Vincent J. Creasi		

The many requests for information and statistics concerning the lightning phenomenon which the Technical Information Section has received from military agencies have led to the compilation of these references. For the most part, the sources selected for inclusion in this bibliography refer to lightning as it occurs in the atmosphere rather than laboratory experiments or studies. Much of this bibliography was compiled using facilities of the various libraries in the Washington Metropolitan area, such as the Library of Congress and the Atmospheric Sciences Library, Silver Spring, Maryland. The help of librarians of these organizations is gratefully acknowledged. Even though not indicated, some items listed may be available in libraries other than those whose library designation is shown.

In general, this bibliography search was limited to the six-year period, 1964-1969 and the search terminated 31 October 1969.

Entries are listed alphabetically by author by year of publication but are numbered consecutively throughout the text. The references listed do not contain all available items but an attempt was made to include a representative grouping. Other excellent entries may be available but did not come to the attention of the authors. An index of the references by subject material is included on page vi.

November 1969

USAF ETAC TN 69-8

It will be noted that the report of a major project, THEMIS, on weather phenomena, Contract No. DAAB07-68-C-0083, for the Dept. of the Army, Electronics Command, by Oklahoma State University, School of Electrical Engineering is abstracted and included as a separate entry (page 37) due to the structure of the report (main report plus five individual studies).

In addition to the annotated listing of publications, a supplemental listing of several textbooks which contain certain generalized information on lightning is included. This listing, like the publication listings, does not contain all available texts, nor are those shown considered as superior to the other fine textbooks which certainly are available but did not come to the attention of the authors.

The authors wish to thank the personnel of the Editorial Section, Information & Publication Branch, USAF ETAC for their assistance in preparing this bibliography with special thanks to Miss Gertrude K. Holtzmann who typed the many abstracts required to complete this technical note.

V.J. Creasi  
Chief, Technical Information Section

## SUBJECT INDEX

<u>Subject</u>	<u>Item Numbers</u>
Ball lightning	5, 20, 40, 54, 61, 62, 85, 90, 97, 116, 123, 124
Damages, deaths, injuries, fires, hazards and strikes to aircraft, missiles and aerospace vehicles, weapons systems, etc.	1, 3, 11, 16, 30, 36, 37, 40, 41, 48, 49, 50, 57, 63, 69, 70, 71, 76, 78, 79, 81, 82, 84, 87, 89, 94, 102, 112, 116, 120
Electrical processes	2, 7, 9, 23, 31, 32, 35, 39, 44, 47, 51, 59, 60, 61, 64, 66, 83, 86, 102, 104, 105, 107, 120, 122
Measurements	4, 7, 8, 10, 12, 13, 15, 17, 21, 22, 24, 25, 26, 29, 30, 33, 34, 38, 43, 49, 55, 72, 75, 81, 82, 88, 92, 93, 99, 100, 101, 106, 107, 112, 113, 114, 115, 119, 120, 125
Meteorological factors	4, 7, 9, 22, 23, 39, 42, 48, 57, 88, 92, 118
Photography	8, 26, 29, 45, 46, 49, 50, 51, 60, 65, 79, 109, 110, 111, 112, 121
Pressure waves, temperatures, etc.	18, 19, 50, 59, 96, 108, 119
Protection devices, suppression, etc.	6, 11, 21, 71, 73, 82, 86, 89, 91, 118
Radiation	2, 14, 15, 20, 28, 44, 68, 74, 95, 103, 109, 121, 123
Research and theory	5, 23, 42, 58, 60, 61, 64, 67, 69, 71, 77, 80, 83, 85, 86, 90, 100, 103, 104, 106, 108, 117, 123
Spectrum	14, 27, 34, 43, 44, 52, 53, 56, 68, 74, 80, 95, 100, 103, 109, 111, 119
Strokes, cloud-to-cloud, cloud-to-ground, etc.	2, 7, 8, 9, 10, 12, 13, 16, 18, 19, 22, 27, 28, 30, 32, 33, 45, 46, 47, 51, 52, 58, 59, 61, 65, 66, 70, 72, 77, 92, 98, 99, 100, 101, 102, 104, 105, 106, 107, 108, 109, 114, 115, 120, 122, 125

A  
SELECTED ANNOTATED  
BIBLIOGRAPHY ON LIGHTNING  
(1964 - 1969)

1964

1. Appleman, Herbert S. Danger to Jet Aircraft from Lightning. AWS, Scott AFB, Ill. TR179, July 1964, 9 p. AD 602765

...This report presents the latest available information on lightning hazards to jet aircraft. Included are the temperature and altitude range where most strokes are encountered. A brief discussion of the type of damage likely to be included, and a somewhat more detailed look into the possibility of fuel-tank explosions due to lightning and electrostatic discharges. It appears that, while the possibility of such explosions is small, aircraft using JP-4 fuel are generally more vulnerable to this hazard than those using gasoline or kerosene. It is concluded from this and other hazards associated with JP-4 that jet passenger aircraft, at least, should use kerosene fuels where possible. (Author)

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2. Brook, M. and Kitagawa, N. Radiation from Lightning Discharges in the Frequency Range 400 to 1000 Mc/s. J. Geophys. Res. Vol. 69, No. 12, June 15, 1964, pp. 2431-2434. DAS P col.

...Simultaneous records of electrostatic field, field change, and radiation at 420 and 850 Mc/s were obtained for lightning flashes from 10 to 30 km distant. At these frequencies, the principal source of radiation appears to be associated with the development of streamers in the breakdown process. Strong radiation is associated with the stepped and dart leaders and with the K changes in both the intracloud and cloud-to-ground flashes. The return stroke does not always produce detectible radiation at these frequencies; in about 50% of the cases the radiation is absent or appears only after a delay of 60 to 100  $\mu$ sec after the onset of the return stroke. This delay is attributed to the absence of radiation associated with breakdown streamers until the return stroke reaches the top of the channel within the cloud. A cessation of the dart leader radiation of 50 to 150  $\mu$ sec before the return stroke also suggests that the radiation occurring during the dart leader phase is produced primarily within the cloud. (Author)

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3. Changnon, Stanley A. Climatology of Damaging Lightning in Illinois. MWR Vol. 92, No. 3, March 1964, pp 115-120, 12 refs, 3 figs, 4 tables. DAS M(05) U587m.

...Statistics on the incidence of damaging lightning in Illinois during the 1914-1947 period were gleaned largely from published and unpublished records of the US Weather Bureau to perform a climatological investigation. On the average, damaging lightning was most frequent during July and August. Normally, 14 days per year had damaging lightning and during 1926-1947 period lightning was responsible for more deaths than any other form of severe weather. Other forms of severe weather occurred on less than 50%



November 1969

of the days of damaging lightning. On an areal basis, damaging lightning occurred most frequently in west-southwestern Illinois which is the same area that has been found to have a high incidence of thunderstorms, tornadoes, hailstorms, and excessive rainstorms. Lightning caused deaths and injuries to a greater percentage of the rural population than of the urban population of the State. In rural areas the structures most frequently damaged by lightning were farm barns, whereas in urban areas residences were the structures most frequently damaged. (Author)

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4. Dennis, Arnett S. Lightning Observations From Satellites. Final Report, SRI, Menlo Park, Calif. NASA CR 60906, N 65-17404. SRI Project 4877. December 1964, 94 p. refs. DAS M(051) S78511.

...The feasibility of observing lightning from satellites is examined in the light of the effects produced at satellite heights by a lightning flash and of the statistics of lightning occurrences. A sferics detector operating around 600 Mc could be used on a low-orbit satellite at, e.g., 1000 km, but could not be used on a satellite in a stationary orbit (at 37,000 km) because of the low signal-to-noise ratio. The short-period variability in flashing rates imposes a lower limit of about 20 flashes per resolution element per observation. This requirement, examined in the light of typical flashing rates and the mechanics of satellite orbits, limits the spatial resolution of the optimum sferics satellite to some 150 km. To realize such resolution without the acceptance of severe limitations upon coverage, it would be necessary to use direction-finding equipment, capable of watching several resolution elements simultaneously. For an elementary system using a fixed antenna, 1000-km resolution would be more appropriate. The potential value of lightning observations from satellites in the fields of meteorology, climatology, atmospheric electricity, geophysics, and radio engineering is examined. It is concluded that such observations would be of some value in radio-noise studies but that their impact upon the other fields would be very slight. (Author)

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5. Dewan, Edmond M. Attempted Explanation of Ball Lightning. Rept. No. AFCRL 64-927, Physical Scien. Res. Paper No. 67, Air Force Cambridge Res. Labs., November 1964. AD 608969.

...Ball lightning has until this time defied physical explanation. This report summarizes the requirements to validate any theory on ball lightning. Finkelstein and Grant's new theory is examined. Previous theories discussed are: combustion, confined plasma, dust, electromagnetic radiation, cosmic ray, and quantum mechanics. (fr. Author abs.)

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6. General Electric Co. A Feasibility Study of Improved Lightning Protection Systems. Final Rpt, Rpt. No. 64PT146, Contract NBy 33260, Pittsfield, Mass, Aug 1964, 46 p. AD 451034.

...The present state of the art does not warrant a direct programmed attempt, at this time, to provide lightning protection by the use of ionized media. Neither the ion density required to make an effective column nor the means to economically and safely establish the column are known. (fr Author's abs)

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7. Kasemir, Heinz W. The Lightning Discharge. U.S. Army Electronics Laboratories, Fort Monmouth, N.J. USAEL Technical Report 2401, May 1964. DAS M(055) U5812te no. 2401. AD 603388.

...The stationary electric field inside a thunderstorm, which is generated by the movement of charged precipitation particles, causes the lightning discharges. In the electric field of the lightning stroke, the distribution of the stationary field in the cloud is reflected. This report shows how different types of lightning strokes (cloud or ground discharges) are connected with different kinds of field distributions in the thundercloud. This leads to certain conclusions of the precipitation pattern and the development stage of the thunderstorm. Electric field and sferics records of different types of thunderstorms are discussed, and useful parameters in the field records are pointed out to determine characteristic electric features of the thunderstorm. (Author)

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8. Kenyon, Richard E. An Electro-Optical System for the Study of Cloud-to-Ground Lightning. Lowell Technological Institute Research Foundation. Final report, Contract No. AF19(628)2972. Dec 1964. AD 613544. DAS M(051) L916fie.

...This report describes the objectives, and progress of work which was initiated under Contract No. AF19(628)-2972 on 1 June 1963, and ended on 30 September 1964. Efforts included the design, fabrication, test and operation of a system of electro-optical instrumentation for recording by electronic and photographic means, parameters of cloud-to-ground lightning strokes. A complete description is given of the instrumentation, test results and field operations resulting from this program. After field tests in the spring and summer of 1964, the instrumentation was shipped to Kissimmee, Florida and was set up to obtain photographs of lightning. The Florida field experiment was conducted in cooperation with the Air Force Hyperbolic Direction Finding Network which was prepared to record the sferics produced by the lightning strokes being photographed. Due to an unusual period of low incidence of thunderstorm activity, no photographs were obtained by the instrumentation in Florida while it was being operated by Foundation personnel. Later in the summer, a few photographs were obtained by Air Force personnel using XR film made by Edgerton, Germeshausen and Grier. However, the film was heavily overexposed, and no prints for analysis had been produced at the time of this report. (Author)

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9. Klapper, J.J. et al. Lightning Phenomena Investigation. General Electric Co. Syracuse, N.Y. Final Report. Contract No. AF29(601)-5402. Kirtland AFB, NMex. AF Weapons Lab. Mar 1964. 84 p. WL-TDR-64-21; AD 440274.

...The lightning-phenomena investigation program was designed to determine induced voltage and currents in certain selected missile-site cables as a result of a lightning discharge on or near the instrumented SM-78 site. The characteristics of the lightning discharge, which produced the induced signals, were measured; in addition, background meteorological measurements were made to facilitate the analysis of the storm event and the resulting data. Limited oscillographic surge data are presented on the only three storms that occurred in the vicinity of the instrumented site. Data are also presented on the 6-month continuous monitoring period on the meteorological parameters, point discharge current, and the atmospheric electric gradient. (Author)

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10. Leushin, N.I. The Amount of Summer Lightning over the European USSR. AFSC, Foreign Technology Division, FTD-TT-65-1798, translated from "Meteorologiya i Gidrologiya," No. 9, 1964, 15 p. 2 figs, 2 tables, AD 635827.

...The article describes a method of constructing charts of lightning distribution over the European USSR on the basis of data obtained during the period 1958-1960 by means of the European cluster of direction-finding equipment. Characterizing thunderstorm activity not by the number of thunderstorm days but by the number of lightning strokes in the examined territory is proposed. The direction-finding method makes it possible to obtain charts of the average distribution of discharges in various periods. These charts make it possible to trace the development of thunderstorm activity during a day. (Author)

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11. Newman, M.M., et al. Lightning Protection Measures for Aircraft Fuel Systems. Phase I. Federal Aviation Agency, Wash., D.C., May 1964 FAA ADS-17, Contract No. FA 64 WA-4960. AD 603232.

...Lightning is receiving increased recognition as a possible hazard to aircraft and an intensive 4-month program, covered in this report, on Phase I, demonstrated the existence of possible ignition sources in a typical aircraft wing-tank section as well as some feasible ignition source reduction measures. The facilities used in creating a lightning environment were further developed and cooperatively applied by LTRI in the Atlantic Research Corp. Phase II portion of the program which studied techniques in quenching ignited vapor inside fuel systems (Report FAA-ADS-18). (Author)

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12. Newman, M.M. Triggered Lightning Discharges and Application to V.L.F. Propagation Studies. Lightning and Transients Research Inst., Minn., Minn. Final rept. pt.1, Oct 1964. 23 p. Rept. No. L T-417. Contract AF19(604)-7984, Proj. 8653. AFCLRL 64-859 I. Unclassified report. AD 616550.

...Natural lightning discharge observations in VLF propagation studies would be greatly helped by direct measurements of the lightning discharge currents corresponding to received wave shapes at various locations. Consequently, a technique for triggering, recording and identifying natural lightning discharges has been evolved by rocket-launching a conducting wire into charged thunderstorm clouds, and superposing a 1000 mega-watt peak radiated power 'signature' pulse. Thunderstorm areas of greatest overhead charge intensity were followed by monitoring gradient variations at sea, with an initial frequency of triggering of 2 discharges brought down out of 5 rocket firings of 1000 ft wires. Corona current measurements on the wire on the way up indicated negligible disturbances of the cloud charge before the actual lightning stroke was triggered. (Author)

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13. Ogawa, T. and Brook, M. The Mechanism of the Intracloud Lightning Discharge. J. Geophys. Res. Vol. 69, No. 24, pp. 5140-5150, Dec 1964. DAS P col.

...Measurements of intracloud lightning discharges are presented and discussed with particular emphasis on the relationships between potential

## 13. (cont)

gradient, potential gradient changes, and K changes. An analysis of the intracloud lightning discharge is given in terms of an advancing streamer model. The observed variations of electric field with time and distance in the initial part of the discharge are consistent with a model which effectively lowers positive charge in the cloud, in agreement with the model proposed by Takagi but at variance with the earlier results of Smith. The final, or J-type part of the discharge consists primarily of negative recoil streamers (K changes) which occur when the initial positive streamers contact regions of concentrated negative charge. The recoil streamers, as seen in photographs of cloud-to-air discharges, originate at the tip of the advancing streamer and travel back along the channel toward the source in a manner analogous to the development of the return stroke following the dart leader in the cloud-to-ground discharge. The K change is estimated to involve currents from 1000 to 4000 amp; a K-change streamer velocity of  $2 \times 10^8$  m/sec is estimated. (Author)

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14. Salanave, Leon E. The Optical Spectrum of Lightning. Inst of Atmospheric Physics, The Univ. of Arizona, Tucson, Ariz. Advances in Geophysics. Vol. 10, 1964. DAS 551.082 A244 v.10.

...The radiation given off by lightning in the atmosphere may be considered as a variable component of the earth's spectrum. It is natural to think of studying the optical spectrum of lightning with the same instruments and comparatively little has been done in this field. It is the purpose of this article to present recent spectroscopic results of improved quality, together with a brief discussion of some of the interesting features of such spectra - particularly as these may suggest how optical radiation from lightning can show up in the spectrum of the earth or some other planet whose atmosphere generates electrical discharges. (Author)

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15. Stahmann, J.R. Laser Type Ultra-Violet Radiation Feasibility for Lightning and Atmospheric Propagation Studies. Lightning and Transients Research Inst, Final Rept, L-T-417, AFCL 64-859, AF19(604)-7984, Proj. 8653, Oct 1964, 22 p. AD 609217.

...The feasibility of a laser type ultra-violet source to trigger lightning for natural lightning channel studies is considered. (Fr. Auth Abs).

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16. Stahmann, J.R. Natural Interference Control Techniques. Part III: Electromagnetic Transient Penetration of Aerospace Vehicle Systems. Lightning and Transients Research Inst., Minneapolis, Minn. Oct 1964. 41 p. refs. Contract AF33(657)-10904, L&T-424; ASD-TDR-63-370, Pt III; AD 609218.

...Practical metal skin enclosures such as aircraft, missiles, and other aerospace vehicles and weapons systems usually have electrical discontinuities at joints, access door, inspection panels, fuel caps, ports, covers, and other points due to construction and operational requirements. The current or electromagnetic fields of direct and nearby indirect lightning strokes may then penetrate the enclosure through these discontinuities, producing high induced voltages on the inside of the enclosure.

## 16. (cont)

The cables connected to rocket vehicles prior to launch also can cause voltages to be coupled inside the vehicle during a lightning stroke. Lightning plasma and pressure waves from strikes near an aircraft fuel vent may cause fuel vapor ignition and flame propagation into the fuel tank. Further study and evaluation of the fuel vent problem, including plasma extent, spark showering, streamer ignition, molecular plasmas, and effects of airflow about the fuel vent, as well as the new lightning diverter and flame arrester designs, are recommended. (Author)

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17. Uman, M.A. The Diameter of Lightning. J. Geophys. Res. Vol. 69, No. 4, pp. 583-585, 15 Feb 1964. DAS P col.

...A determination of the diameter of the lightning stroke is made by allowing lightning discharges to pass through fiberglass screen. Twelve holes were produced (melted) in fiberglass screen by lightning discharges; six holes with diameters between 2 cm and 3.5 cm, six holes with diameters between 2 mm and 5 mm. (Author)

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18. Uman, Martin A. The Density, Pressure and Particle Distribution in a Lightning Stroke Near Peak Temperature. J. Atmos. Sciences, Vol. 21, No. 3, May 1964, pp. 306-310. DLC QC 851.A283.

...The first determination of the density, pressure, and particle distribution in a lightning stroke near peak temperature is presented. The number of electrons per air atom is about 0.81; analogous quantities for 25 species of air particles present in the stroke at 20,000K are presented. (Fr. Author Abs)

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19. Uman, Martin A. The Mass Density, Pressure, and Electron Density in Three Lightning Strokes Near Peak Temperature. J. Geophys Res. Vol. 69, No. 24, 15 Dec 1964, pp. 5423-5424. DAS P col.

...Properties for mass density, pressure, and electron density of three lightning strokes at temperatures near 24,000°K are given. There is a possibility that lightning strokes reached higher temperatures for shorter durations, which made the temperature immeasurable. (DLB)

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1965

20. Andersen, W.H. Energy Source for Ball Lightning. JGR, Vol. 70, No. 6, Mar 15, 1965, pp. 1291-1293. DAS P col.

...It is shown that the EM radiation frequencies from external sources required to form ball lightning (according to the Kapitza theory) are emitted during the collision of charged water drops. Calculations show that a reasonable volume of nominally-charged droplets will provide the

## 20. (cont)

energy necessary for the lightning ball, but a prohibitively large volume of ordinary rain drops is required. It is hypothesized that shock from ordinary bolt lightning may provide the requisite droplet-charging energy, either through liquid breakup in a polarizing field or by gas friction. Interactions or convergence of the EM radiation may be of importance in producing the required localized energy densities. (Author)

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21. Arrowsmith, E.B. Lightning Prediction and Protection Techniques. Aerospace Corp. El Segundo, Calif. Technical Operations. Tech Operating Rpt. Oct 1965, 82 p. AD 474610.

...The lightning protection at present launch support facilities was surveyed. An evaluation is presented and intended to help determine possible methods of reducing not only damage from lightning strikes, but also the resulting delays in launch schedules. As a basis for the evaluation, information is provided on lightning phenomena, lightning protection devices and systems, instrumentation for detecting and predicting thunderstorm activity and for measuring and evaluating lightning discharges, as well as an example of a lightning incident at a launch pad. Recommendations are made for improved protection. (Author)

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22. Battan, Louis J. Some Factors Governing Precipitation and Lightning from Convective Clouds. JAS, Vol. 22, No. 1, Jan 1965, pp. 79-84. DLC QC 851.A283.

...Two groups of days, one with "heavy rain" and one with "light rain," have been studied. Radar observations, cloud photographs and visual counts of cloud-to-ground lightning were examined. It is concluded that, at least in convective clouds in southeastern Arizona and probably in convective clouds in other geographical regions as well, the microphysical properties of the clouds are not of dominant importance in determining how much precipitation reaches the ground. It is inferred that the quantity of rainfall is mostly governed by those properties of the atmosphere which determine the size, strength and duration of the updrafts. The observations also show that as the quantity of rainfall increases so does the frequency of cloud-to-ground lightning. (Author)

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23. Byers, Horace R. Relation of Lightning and Thunderstorms to Meteorological Conditions. International Conference on Atmospheric and Space Electricity. 3rd, Montreux, Switzerland, May 1963, Problems of Atmospheric and Space Electricity: Proceedings of the Conference. Amsterdam, 1965. pp 491-496. Figs. refs. DAS (M94 I61p).

...Four meteorological problems related to thunderstorms, lightning, or atmospheric electricity in general are treated. First, the significance of the exchange layer and its role in convection and atmospheric electricity is discussed. Secondly, the role of thunderstorms in the general circulation of the atmosphere is stressed, taking into account that it is only through the giant thunderstorms of the tropics that heat can be transported upward to compensate for the net radiational cooling in the upper troposphere in these latitudes. This upward flux of heat is

## 23. (cont)

necessary to account for the observed general circulation. A third topic is that of convection models, and it is pointed out that the updraft and downdraft areas represent only a small fraction of the thunderstorm area. The updraft is surrounded by clear air only in the towers that project upward from the main mass of the storm. The final topic is that of the nature of hydrometeors, which are regarded as important in the thunderstorm electrical generation. Several processes are available in cumulus clouds for producing ice or large liquid drops. Lightning does not seem to depend on any one particular process. (Author)

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24. Harrison, Henry T. UAL Turbojet Experience with Electrical Discharges. United Air Lines, Inc. UAL Meteorology Circular No. 57. Jan 1965, 89 p. refs. DLC TL 556.U2.

...Roughly 40% of all discharges occur in areas where no thunderstorms are reported. Thunder or lightning is reported in the general area in the remaining 60% but there is evidence for thunderstorm at the spot of discharge in only 33% of all occurrences. Any weather map situation which will produce precipitation seems to be capable of setting up discharge situations. The typical local staging for a "strike" is one in which high electric potential already exists in a band or shaft of precipitation but nature gives the impression of needing an assist from the aircraft to trigger it off. Turbine aircraft rarely experience discharges at normal cruising levels but suffer about the same exposure as propeller aircraft around airport areas. Damage patterns on turbine aircraft appear to be about the same as those with propeller airplanes. (Fr. Author Abs)

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25. Kinzer, G.D., et al. Locating and Tracking Areas of Lightning. Weather Bureau, ESSA, U.S. Dept of Commerce, Wash. D.C. Tech Note 3-NSSL-24 "papers on Weather Radar, Atmospheric Turbulence, Sferics and Data Processing," National Severe Storms Laboratory Report No. 24, Aug 1965, pp. 72-81. DAS M(055)v5852 re No. 24.

...The amplitudes of component frequencies greater than 10 kilocycles per second in the Fourier spectral representation of electric signals from lightning are inversely proportional to range beyond about 25 nm. On this basis, a system for locating effective positions of lightning flashes from measurements at two or more receiving stations is being developed to operate over a range extending from 40 to 200 nm. (Author)

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26. Kitagawa, N. Types of Lightning. International Conference on Atmospheric and Space Electricity, 3rd Montreux, Switzerland, May 1963, Problems of Atmospheric and Space Electricity: Proceedings of the Conference. Amsterdam, Elsevier, 1965. pp. 337-348. Figs., refs. DAS (M94 I61p).

...Extensive lightning measurements made in New Mexico, which used moving-film cameras and electric-field recording oscilloscopes simultaneously, have revealed some new aspects of lightning flashes and have yielded the value of the charge brought to Earth by individual discharge elements. In very active storms, 90% of cloud-to-ground flashes are multiple flashes which involve 7 strokes on the average. Of the multiple flashes, 50% are

26. (cont)

hybrid flashes which involve at least one long-continuing stroke (defined as one lasting longer than 40 m sec). The average value of negative charge lowered to Earth in hybrid flashes is 34 C, compared with 19 C for the discrete flashes which involve no long-continuing current. As the difference is accounted for by the presence of the long-continuing current, this discharge element is found to be a very efficient agent which lowers the cloud charge to Earth and which inevitably produces a large slow positive change on the electric-field record. (Fr. Auth. Abs.)

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27. Krider, E. Philip. Time Resolved Spectral Emissions from Individual Return Strokes in Lightning Discharges. J. Geophys. Res., Vol. 70, No. 10, 15 May 1965, pp. 2459-2460. DAS P col.

...Four emission factors of lightning strokes are considered: peak wavelength (angstroms); peak transmission (%); half-width (angstroms); and principal lightning emission. (DLB)

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28. Orville, R.E. and Uman, M.A. The Optical Continuum of Lightning. J. Geophys. Res., Vol. 70, No. 2, 15 Jan 1965, pp. 279-282. DAS P col.

...The optical continua of several lightning strokes are presented. In general, the continuum intensity of lightning increases toward the short wavelengths in the wavelength region from 5900Å to 3900Å. There appear to be no significant differences between the form of the intense streaks of continuum and the form of the dim continuum. The plots of continuum intensity versus wavelength have too great a curvature for the continuum to be due to either blackbody radiation or bremsstrahlung emitted at constant temperature. Possible explanations for the observed form of the continuum are advanced. The lightning continuum is found to be similar in form to the continuum of a long laboratory spark in air. (Author)

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29. Salanave, Leon F. Lightning Photography and Counting in Daylight, Using H Alpha Emission. J. Geophys. Res., Vol. 70, No. 6, 15 Mar 1965, pp. 1285-1290. DAS P col.

...Narrow-band interference filters have been used successfully in photographing lightning discharges in daylight and in the design of an improved lightning flash counter. Preliminary results are presented along with a discussion of design principles and possible further applications of the techniques. (Author)

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30. Sly, W.K. A Convective Index in Relation to Lightning Strikes in Northwestern Alberta, Canada. Dept. of Transport, Toronto. Meteorological Branch. CIR-4220; TEC-566. 21 Apr 1965. 17 p. refs. DAS M(O6) C212c Tec 566.

...A convective index for Grande Prairie is correlated with the incidence of lightning strikes in the Grande Prairie forest area. A critical value



## 30. (cont)

for the incidence of lightning evolves and suggestions made for its practical application. Similarly, convective indices for individual lookout towers are shown to have a relation to the incidence of lightning in the vicinity of the tower. (Author)

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31. Smith, Richard W. et al. Lightning Tests in the Minuteman High Frequency Communications System. A.F. Special Weapons Center, AFSWC TR-64-8, Proj 133A002, Kirtland AFB, N.M., Jan 1965, 52 p. AD 457334.

...The lightning tests on the Minuteman High Frequency Communications System were designed to determine induced voltages and currents in certain control cables as a result of lightning strikes. (Fr. Author Abs.)

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32. Takeuti, T. Studies on Thunderstorm Electricity, Pt. I. Cloud Discharge. J. of Geomagnetism and Geoelectricity, Vol. 17, No. 1, 1965, publ. by the Society of Terrestrial Magnetism and Electricity, Japan, Tokyo, 1965, pp. 59-68. 14 refs, 12 figs, 2 tables. DLC QC801.J63.

...To study the electrical process in cloud discharge and the charge distribution in thunder-clouds, the electrostatic field changes due to a cloud discharge have been recorded simultaneously at three field sites. It has been found that there are three types of thunder-cloud: Type I predominantly produces an upper-positive vertical dipole discharge; Type II, an inclined or horizontal discharge; Type III, an upper-negative vertical discharge. Type III is found likely to have more or less thin distribution of negative electric charge on top of or just above it. (Auth.)

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33. Taylor, A.R. Diameter of Lightning as Indicated by Tree Scars. JGR, Vol. 70, No. 22, 15 Nov 1965, pp. 5693-5695. DAS P col.

...The diameter of lightning strokes were estimated from lightning effects on trees in western Montana. Two photographs are included showing scars from strikes on Douglas firs. (ALS)

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34. Uman, M.A. and Orville, R.E. The Opacity of Lightning. J. Geophys. Res. Vol. 70, No. 22, 15 Nov 1965, pp. 5491-5497. DAS P col.

...Lightning channels studied are shown to be optically thin to two N II multiplets by comparing the relative intensities of multiplet members with the predictions of theory and with previous laboratory measurements. From this result it is shown that the lightning channels studied are optically thin to all measured N II and O II line radiation and to the high-temperature continuum. The absorption coefficient for N II  $4630.5\text{\AA}$  is calculated. From this calculation and the requirement of optical thinness, the effective diameter within which the radiating N II atoms are contained is determined to be less than a few millimeters. The opacity of the lightning channel to neutral atom radiation and to the low-temperature continuum is considered. The results of a paper by Zhivlyuk and

## 34. (cont)

Mandel'shtam in which the lightning channel is assumed to be optically thick to three N II lines and one O II line are discussed. (Author)

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35. Valley, Shea L. (ed). Handbook of Geophysics and Space Environments. AFCL, OAR, USAF. 1965. 22 chapters. DAS 511v581ha 1965.

...Chapter 8 Atmospheric Electricity contains articles on thunderstorm electricity, electrostatic field patterns, precipitation static, power line and building strikes, possible strike patterns, charge and field variations, etc. (ALS)

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36. Vonnegut, Bernard I. Electrical Behavior of an Airplane in a Thunderstorm. Little (Arthur D) Inc., Cambridge, Mass. prepared for FAA. Contract # FA64 WA-5151, Tech Rept ADS-36, Feb 1965. AD 614914.

...By processes as yet poorly understood, extensive regions of both positive and negative electric charge form in large convective clouds. These clouds are the primary source of the lightning discharges that sometimes strike airplanes. Airplanes in flight can develop electrical charges on their surface as the result of a variety of processes but the maximum amount of charge that they can carry is limited by point discharge and is negligibly small compared to the charge transferred by a lightning discharge. Although the amounts of net or induced charge on the airplane are small compared to the amount of charge in the thundercloud, these charges can locally cause an appreciable intensification of the electric field of a thunderstorm. (Author)

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1966

37. Australia, Commonwealth of, Notes on Lightning Strikes on Aircraft. Bureau of Meteorology, Australian Meteorological Magazine, Vol. 14, No. 4, Dec 1966, pp. 174-177. DAS M(05) A938.

...Lists lightning strikes reported on aircraft, from the Dept of Civil Aviation Melbourne, during the period from 9 Dec 1964 to 6 Jul 1966. Gives location, height, type aircraft and cloud cover and type. (ALS)

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38. Boer, J.H. A Verification of the Accuracy of Short-Range Lightning Counters. Illinois State Water Survey, Atmospheric Sciences Section, Urbana, Ill. (In its Relation of Lightning, Rainfall and Hail to the Properties of Mesoscale Meteorological patterns). pp. 49-59, Nov 1966. DAS M(055)I29p.

...The instrumentation, observational techniques, and verification experiments used to determine the accuracy of short-range lightning counters are described. A circuit diagram of a modified version of the Pierce

## 38. (cont)

lightning counter is given, as well as the aerial set-up of the lightning counter. All observed flashes occurring in an isolated storm were plotted and compared with counted flashes; the results of 10 comparisons are summarized in tabular form. The data indicate that for most storms the counts at ranges below 15 km are accurate within 15%. The apparently high degree of accuracy of the short-range counters suggests that the parts of the field changes that trigger the counters have more or less equal intensity. This would indicate that the first return strokes of different multiple flashes transport approximately equal amounts of charge to earth. (Author)

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39. Byers, Horace R. The Relation of Lightning and Thunderstorms to Meteorological Conditions. Cloud Physics Laboratory, Dept. of Geophysical Sciences, The University of Chicago, Technical Note No. 32, 15 Jan 1966. AD 628598.

...The main feature that distinguishes meteorology from the other sciences that might concern themselves with the atmosphere is its emphasis on air circulation. These circulations, ranging from small turbulent eddies to the air flow over the planet as a whole, influence the distribution of electrical properties. Thus, a two-way relation between lightning, as well as all the other electrical phenomena, and meteorological conditions exists. (Author)

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40. Charlier, Louis-Albert. Kugelblitz-Beobachtung in Vorarlberg. [Ball Lightning Observations in Vorarlberg.] Wetter und Leben, Vienna, 18(9/10): 204-205, 1966. DAS M86 W542.

...Describes an occurrence of ball lightning over the Duns Mountain on May 17, 1966 and the damage that it caused. It came from the district of Duns-Schlins-Jagdberg-Jupident. (ILD)

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41. Falconer, R.E. Lightning Strikes a Parked School Bus. Weather, London, 21(8):280-281, Aug 1966. Figs. DAS M(05) R888w.

...On the evening of July 9, 1960 lightning struck an empty school bus near New York. Photographs and a diagram are used to indicate where the lightning struck and the pattern of damage. The charge entered the bus at its highest point and discharged through the metal rims of the wheels. Asphalt and dirt were torn up into a dendritic pattern of little zigzag channels spreading away from the wheels where the discharge hit the ground. Asphalt was blown on to the top of the bus. The only damage to the bus was the melting of a metal ring near to the place where the lightning entered the bus. (RB)

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42. Feteris, P.J. Relation of Lightning, Rainfall, and Hail to the Properties of Mesoscale-Meteorological Patterns. Ill. State Water Survey, Atmospheric Sciences Div., at U. of Ill., First Progress Rept., N. Science Foundation GP-5196, Urbana, Nov 1966 59 p. 17 refs. Tables, Fig, formulae.

42. (cont)

DAS M(055) I29p no. 1.

...This report describes work performed as a part of a diagnostic study which is expected to improve our knowledge of the production of rainfall, lightning discharges, and hail in convective storms as related to a number of time-dependent meteorological variables. This study differs from previous research in that it attempts to assess the statistical significance of certain meteorological parameters governing the production of precipitation in relation to all other significant predictors. (Author)

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43. Galejs, Janis. Amplitude Statistics of Lightning Discharge Currents and ELF and VLF Radio Noise. Sylvania Electric Products, Inc., Waltham, Mass. Applied Research Lab. Contract Nonr-3185(00)FEM, Sep 1966, 23 p. refs. AD-642539.

...The received noise is considered as the result of integrating several atmospherics during the response time of the receiver. The probability distributions of this noise, and of the current in lightning flashes are related by a twofold Hankel transform. The derived current for very large amplitudes is found. The resulting received noise is characterized by a Rayleigh distribution for small signals, and the distribution is inversely proportional to the squared amplitudes for large signals. The present calculations provide amplitude distributions of the received noise which approximate measured noise characteristics more closely than in earlier work, which was based on the approximation of measured current distributions by two exponentials. (Author)

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44. Hill, R.D. Electromagnetic Radiation from the Return Stroke of a Lightning Discharge. J. Geophys. Res. Vol. 71, No. 8, 15 Apr 1966, pp. 1963-1967. DAS P col.

...The electromagnetic spectrum radiated from a typical lightning stroke has been calculated using a particular model of the return stroke. The main features of this model are that a uniform distribution of electrons, laid down by the leader discharge between cloud and ground, is relieved by a return stroke which has the form of a step-function current-pulse traveling from ground to cloud. Good agreement with experiment is found in the frequency region of maximum radiation intensity from approximately 1 to 15 kc/s. (Author)

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45. Jones, Herbert L. et al. Review of Frequency Spectrum of Cloud-To-Cloud and Cloud-To-Ground Lightning. IEEE Transactions on Geoscience Electronics, N.Y., 5(1):26-30, Mar 1967. DLC. Also issued in Conference on Radar Meteorology, 12th, Norman, Okla., Oct 1966, [Proceedings] Boston, American Meteorological Society, 1966. pp 174-179. Figs, refs. DAS (M01.81 R124pr).

...Using a visual periscope-type camera which records the strokes photographically and a second camera that records both the wave form and the associated 150 and 10 kc sec<sup>-1</sup> directional pips, the authors investigated cloud-to-ground and cloud-to-cloud lightning discharges. "There appears

## 45. (cont)

to be a common factor characteristic of all types of lightning discharges resulting in a preponderance of frequency components in the band between 100 kc sec<sup>-1</sup> and 200 kc sec<sup>-1</sup>. A simple mathematical analysis of the tornado pulse generator suggests a 1 km vertical oscillation path for the series of discharges from the generator. (ILD)

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46. Krider, E.P. Some Photoelectric Observations of Lightning. J. Geophys. Res. Vol. 71, No. 12, 15 Jun 1966, pp. 3095-3098. DAS P col.

...During the summer of 1965, a calibrated silicon photodiode and an oscilloscope were used as a fast-response lightning photometer covering the visible and near-infrared regions of the spectrum from 0.4 to 1.1  $\mu$ . Simultaneous still photographs of the discharge channels were taken to determine how the photoelectric pulse profiles depend on the type of lightning (i.e., cloud-to-ground versus cloud-to-cloud) and the geometry of the channels. These observations represent the first attempt at a photometric study of lightning with correlated photographs of the discharge channels. (Fr. Author's Abs.)

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47. Loeb, L.B. The Mechanisms of Stepped and Dart Leaders in Cloud-to-Ground Lightning Strokes. J. Geophys. Res. Vol. 71, No. 20, 15 Oct 1966, pp. 4711-4721. 26 refs, 3 figs. DAS P col.

...Recent observations indicate the rather complete neutralization of volume space charges by induced positive corona streamers. New photographic observations of high-tension power lines in rain and snow storms reveal strong and heavily branched corona streamers from such hydrometeors. A study of uniform field streamer breakdown in midgap in clean gases, just published, has provided additional information essential to the delineation of the processes active in the forging of the channel of the cloud-to-ground stroke. (Author)

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48. Miller, Edward, 1stLt, USAF. Project Rough Rider 1965, Phase I - Phase II, Mar 1966, Deputy for Flight Test, Aeronautical Systems Division, Air Force Systems Command, Wright-Patterson Air Force Base, Ohio, AD 632610.

...This report states the objectives of Project Rough Rider as well as discusses the test instrumentation used on the penetration F-100F aircraft. Other topics covered are flight operations, aircraft damage, location of archived data, and conclusions and recommendations for future thunderstorm penetrations. This report is documentary or historical in nature and gives an overall picture of Project Rough Rider 1965, but not a detailed analysis of the accumulated data. The various sources from which such analyses can be obtained are referenced in the report. (VJC)

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49. Miller, Edward. Thunderstorm Lightning. In AEDC Proc. of the 13th Ann. AF Sci. and Eng. Symp., Vol. III [1966] 23 p. refs. AD 641923.

...An F-100F aircraft was flown into thunderstorms over the south central and southern sections of the United States to get the aircraft struck with lightning as much as possible and to permanently record particular information concerning these lightning strikes. The prototype test instrumentation package had numerous sensing elements located on a majority of those sections of the aircraft which were known to be vulnerable to lightning strikes. The test package proved to be quite a reliable means of obtaining data on lightning strikes to aircraft at altitude. As a result of the project, approximately 15 lightning strikes were filmed striking the various aircraft components while correlating data on the discharge current, time duration to half value and the characteristic wave shapes were permanently recorded via the other test equipment.  
(Author)

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50. Newman, M.M., Robb, J.D., and Stahmann, J.R. Plasma Characteristics of Natural Lightning in Relation to Aircraft. Lightning and Transients Research Inst., Sixth Quarterly Report, L and T No. 455, Contract No. AF33(615)-1974, Minneapolis, Aug 1966, 6 figs, photos, 9 p. AD 814650.

...17 natural lightning discharges out of 23 attempts have been triggered during the past summer's thunderstorm season using the LTRI triggering technique of firing a rocketborne wire 300 meters above the LTRI research ship to trigger the discharge. The discharges were recorded photographically with still and high speed motion picture cameras using negative film and a special extended range film which had a wide exposure latitude. The discharge currents were recorded oscillographically on several time and amplitude scales. Also recorded were the light intensity and pressure waves associated with each discharge. (Fr. Author's Abs.)

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51. Orville, Richard E. Lightning Through a Lens. Natural History. N.Y. 75(1):34-41, Jan 1966. Figs, photos. DAS P col.

...Describes some of the results that have been obtained from photographic studies of lightning. It is suggested that the visible cloud to ground flash may be composed of several processes called strokes. The strokes consist of a leader process which establishes a short circuit between the ground and the return stroke which is the flow of current through the short circuit. Using a technique of recording slitless spectra of lightning, it is possible to study, not only the characteristic emissions from the flash, but also the variations in temperature and density along the channel. It is possible to obtain a spectrum of the flash, time-resolved into its component strokes. Qualitative data can be obtained using color film. Indicates that studies are being continued to correlate luminous emissions of lightning with their electrical characteristics in an effort to obtain a complete description of the lightning flash. (ES)

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52. Orville, Richard E. High-Speed, Time-Resolved Spectrum of a Lightning Stroke. Science, Wash., D.C. 151(3709):451-452, Jan 28, 1966. Fig. refs. DAS P col.

...Reports study of lightning strokes that occurred during an intense storm over Tucson, Ariz., on July 14, 1965. Several time-resolved spectra of single-stroke flashes were obtained. The first time-resolved spectrum

## 52. (cont)

of a return stroke between the cloud and ground was obtained with a slitless spectrograph. The time for luminosity to rise from zero to its peak in a section of the channel is 10 m sec. or less, and the intense emission lines are attributed to singly ionized nitrogen atoms. Several faint lines persisting for 450 m sec. are due to neutral N and O atoms. (ES)

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53. Orville, Richard E. The Colour Spectrum of Lightning. Weather, London, 21(6):198-200, Jun 1966. DAS M(05) R888w.

...During the last 4 yrs, over 300 slitless spectra of lightning have been taken in Tucson, Ariz. This paper presents the first color spectrum of lightning and discusses its qualitative features. The spectrum is presented as a cover picture. Most of the features noted earlier in black and white spectra reported by SALANAVE, ORVILLE and RICHARDS are contained in the color spectrum and the emission lines can be identified by reference to this earlier work. (Author)

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54. Rayle, W.D. Ball Lightning Characteristics. Lewis Research Center, Cleveland, Ohio, NASA TN D-3188, 38 p. 5 figs, 5 tables, 19 refs. Jan 1966. DAS 629.1308 v585 tn D3188.

...Surveys of NASA Lewis Research Center personnel were conducted to obtain information about ball lightning occurrences. A comparison of the frequency of observation of ball lightning with that of ordinary lightning impact points reveals that ball lightning is not a particularly rare phenomenon. Contrary to widely accepted ideas, the occurrence of ball lightning may be nearly as frequent as that of ordinary cloud-to-ground strokes. (Fr. Author's Abs.)

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55. Rossby, Stig A. Sferics from Lightning within a Warm Cloud. J. Geophys. Res., Vol. 71, No. 16, pp. 3807-3809. 15 Aug 1966. DAS P col.

...During a series of observations of UHF sferics at 610 Mhz, lightning was observed in two small cumulus clouds with tops well below the freezing altitude. UHF sferics in association with lightning discharges appear generally as trains of microsecond pulses lasting 10 or more microseconds. The temporal density of pulses in the warm-cloud sferic is less than that in the sferic of a large cumulonimbus. The visible flashes from warm clouds appear to be more frequent, although of shorter duration, than those of a large thunderstorm. (Author)

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56. Salanave, I.E. The Infrared Spectrum of Lightning. Univ. of Arizona, Inst. of Atmospheric Physics. Rept No. Reprint-188, 7 p. 1966. AD 662947.

...Techniques of slitless spectroscopy were used to record lightning spectra to 8800Å. Emissions are due to neutral N, O, and Ar. O2 absorption is prominent. Determination of excitation temperature for neutral atoms is considered, as is the possibility of determining range from O2 absorption. (Author)

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57. Sansom, H.W. A Possible Effect of Lightning on Hail. Weather, Vol. XXI, No. 9, pp. 315, 2 refs, 1 table, Sep 1966. DAS M(05) R888w.

...Information on both lightning frequency and hail damage for 68 hailstorms is given for Kericho, western Kenya. The number of cases of damaging and non-damaging cases are given for intervals between lightning flashes of  $\leq 5$  minutes,  $> 5$  minutes and no lightning or thunder. (VJC)

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58. Srivastava, K.M.L. Return Stroke Velocity of a Lightning Discharge. J. Geophys. Res., Vol. 71, No. 4, pp. 1283-1286, 15 Feb 1966. DAS P col.

...The purpose in the present note is to discuss a new empirical relation for the velocity of the first return streamer in a lightning discharge. (Author)

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59. Stahmann, J.R. Experimental Triggering of Natural Lightning. Lightning and Transients Research Institute. 58 p. 42 figs. 4 tables. 9 eqs. Mar 1966. AD 654886.

...Natural lightning was triggered by directing rockets, trailing thin, stainless steel wire, from the Research Vessel Thunderbolt toward charged clouds. Data concerning current waveform, blast pressure waves and plasma extent were obtained. It was shown that strokes can be triggered about 50% of the time in medium to high electric fields. (Author)

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60. Takeuti, Tosio. Studies on Thunderstorm Electricity, Pt. 2, Ground Discharge. J. Geomagnet. Geoelec., Kyoto. 18(1):13-22, figs, table, refs, eqs., 1966. DLC QC801 .J63.

...The nature of ground discharge has been investigated using the data of electric field measurement, thunder recording, flash photographing, etc. The height of charge center neutralized by a return stroke was found not to increase with the stroke order in contrast with the report given by Malan and Schonland, instead the stroke channel was often found to progress laterally successively. The existence of a continuing discharge process between and after return stroke has been verified in agreement with the respect report given by Malan, and Kitagawa et al. (Author)

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61. Uman, M.A. and Helstrom, C.W. A Theory of Ball Lightning. J. Geophys. Res, Vol. 71, No. 8, pp. 1975-1984, 15 Apr 1966. DAS P col.

...A mathematical theory of ball lightning is presented. Ball lightning is considered to be an externally powered dc phenomenon that results from the funneling of cloud-to-ground current through a region of high temperature and high electrical conductivity. An approximate solution of the equations of current conservation and energy conservation with proper boundary conditions yields a luminous region of air. The predicted ball lightning diameters are in good agreement with observation for reasonable values of current, current density, electric field, and electrical conductivity inside and outside the ball. The luminosity, energy content,



## 61. (cont)

formation, locale, motion, and observed modes of disappearance of ball lightning are discussed. An explanation for the phenomenon of bead lightning is advanced. (Author)

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62. United States, Library of Congress, Aerospace Technology Division. A Monthly Review of Selected Foreign Scientific and Technical Literature Sponsored by the Dept of Defense. Foreign Science Bulletin. Vol. 2, No. 4, 82 p. Apr 1966. AD 631429.

...The present article is concerned with estimating the conventional-explosive energy equivalent of ball lightning. Descriptions of two other observations of ball lightning are included as appendices. (Author)

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63. Vonnegut, B. Effects of a Lightning Discharge on an Aeroplane. (Little, Arthur D., Inc., Cambridge, Mass.) Weather, London, 21(8):277-279, Figs, ref. Aug 1966. DAS M(05) R888w.

...On Oct 15, 1965, at the Salt Lake City Airport, a Convair aeroplane was struck by lightning just as it was taking off. The pilot's account of the incident is reproduced. An extremely loud explosion was experienced on take-off but engine instruments did not record anything untoward. One member of the crew observed a blue-white glow around the nose of the aircraft at the time of the explosion. Part of a tail section was damaged, there were numerous burn marks around the wheel housings, one grounding wire was burnt off completely, and there were holes in the fuselage which might have been made by pieces of flying asphalt. Three large holes were made in the runway asphalt where the wheels were in contact. The largest hole was five ft in diam and 6-8 in deep. (RB)

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1967

64. American Chemical Society. Chemistry and the Environment of Lightning. Special Reports Reprinted from Chemical & Engineering News, Amer. Chem. Soc. Publications, Wash, D.C., pp. 23-24 (Pt III), 1967. DAS 551 C517ch.

...A short description of the various theories advocated as the cause of lightning. Also a brief explanation of the physical processes involved. (DLB)

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65. Berger, K. Novel Observations on Lightning Discharges: Results of Research on Mount San Salvatore. Franklin Inst., Phila, Jnl, 283(6):478-525, figs, refs, Jun 1967. DLC-X1.F8 DAS P col.

...The contents of this article comprise the following: a description of the Mount Salvatore Lightning Res. Station near Lugano, Switzerland including the location and instrumentation; the isoceramic level,

## 65. (cont)

lightning frequency and corona currents; general observation on lightning currents to the Earth; examples of lightning-current oscillograms; statistical data on lightning parameters; purposes of lightning photography on Mount San Salvatore; development of the lightning stroke including a discussion of lightning photography examples, of lightning stroke photographs, photographic evidence of lightning progression establishment of the electrical "bridge" between the downward progression leader and the Earth; steepness of positive and negative lightning currents and its correlation with "connecting streamers;" a brief review of unsolved lightning-stroke problems--whether upward strokes are always "secondary" strokes, i.e., caused by a primary distant stroke; why streamer discharges from a negative tower tip are much longer than those from a positive tower; why do multiple strokes occur only with negative lightning currents, etc.; points of impact of lightning strokes near San Salvatore; consequences of leader development with respect to the "particle area" of lightning rods and to lightning accidents; and a summary of new observations of lightning. (ILD)

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66. Chowdhuri, P. et al. Voltage Surges Induced on Overhead Lines by Lightning Strokes. Institution of Electrical Engineers, London, Proceedings, II4(12):1899-1907, Figs, tables, refs, eqs. Dec 1967. DLC TK1.I4.

...Analyzes the voltage induced on an overhead line by the electromagnetic effects of the return stroke of lightning. The effects of a rectangular return stroke current as well as currents having linearly rising front are analyzed, assuming uniform charge density along the stroke channel and return stroke velocity as a constant parameter. The analysis, which corroborates recent field data, shows that the induced voltage is not entirely a traveling wave phenomenon. Contrary to the previous studies, this study shows that the waveshape of the induced voltage can be bipolar. Furthermore, the magnitude as well as the front time of the return stroke current may be predicted approximately from the oscillogram of an induced voltage. The magnitudes of voltages induced by indirect strokes can exceed the basic impulse insulation level of high voltage systems. (Author)

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67. Coates, C.L. Texas Biannual of Electronics Research. Texas Univ., Austin, Labs. for Electronics and Related Science Research, Report No. RR-6, 257 p. 15 Nov 1967. AD 662359.

...Research topics in progress, recent findings, and future plans in the areas of biomedical electronics; information sciences; physical, quantum, and plasma electronics; and space, atmospheric, and earth radio sciences are presented. (Author)

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68. Connor, T. Robert. The 1965 ARPA-AEC Joint Lightning Study at Los Alamos. Volume I. The Lightning Spectrum. Charge Transfer in Lightning. Efficiency of Conversion of Electrical Energy into Visible Radiation. Los Alamos Scientific Lab N Mex. Rept No. LA-3754, 34 p. 5 Dec 1967 (also see LA-3755 2v). AD 663136.

68. (cont)

...The visible energy radiated (3900 to 6900Å) per unit of length of lightning channel was calculated using time- and wavelength-integrated spectrographic data of the 1965 lightning study. An estimated rain-transmission correction was used. The total energy deposition was calculated, assuming a dipole model of a lightning stroke and using measured values of charge transferred and channel length. The efficiency for conversion of electrical energy to visible radiation is found to be 0.007 plus or minus 36%. (Author)

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69. Fitzgerald, Donald R. Probable Aircraft "Triggering" of Lightning in Certain Thunderstorms. Monthly Weather Rev. Wash., D. C., 95(12):835-842, figs, charts, tables, refs., eq., Dec 1967. DAS M(05) v587m.

...3 aircraft have been used to study the lightning and related cloud physics properties of Fla. thunderstorms. The average probability of a lightning strike to the storm penetration aircraft was 0.021, based on the ratio of aircraft strikes to the total number of strikes during penetration periods. On 2 exceptional days, the probability increased to 1.00 and 0.50. These storms were found to be in an early dissipating stage. The results appear to confirm the suggestion of L.P. Harrison that an aircraft may act to initiate streamers and lightning discharges by suddenly augmenting the field in a localized region in the storm. This effect is most likely to occur shortly after the storm activity has diminished to the point where natural streamer formation is difficult. (Author)

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70. Fuquay, D.M. et al. Characteristics of Seven Lightning Discharges that Caused Forest Fires. J. Geophys. Res., Vol. 72, No. 24, pp. 6371-6373, table, 6 refs, fig, formulae, 15 Dec 1967. DAS P col.

...The hypothesis is advanced that lightning fires are caused by a special type of lightning discharge having a long continuing current phase. Seven ground terminals exhibited fire and all the fires were caused by discharges having at least one long-continuing current phase exceeding 40 m sec duration; of the 856 cloud to ground discharges recorded during 1965 and 1966, about half contained a long-continuing current phase. (Author)

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71. Fuquay, Donald M. Weather Modification and Forest Fires. American Association for the Advancement of Science, Wash. D.C., Publication No. 86, pp. 309-325, figs, photos, refs, 1967. DAS M84.4 S989gr.

...In the discussion of weather modification in relation to forest fires, consideration is given to forest fire conditions, lightning research, the characteristics of mountain thunderstorms, lightning modification, the identification of lightning discharges, and theoretical consideration for lightning suppression. Information from studies on mountain thunderstorms and fire-starting lightning discharges has been used to develop a 3-yr program to evaluate what effect seeding with AgI will have on the frequency and character of lightning discharges from mountain thunderstorms. Data from additional seasons hopefully will provide definite information on whether and how cloud seeding affects the frequency and character of

## 71. (cont)

lightning discharges and how these changes will influence forest fires caused by lightning. (ES)

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72. Galejs, Janis. Amplitude Statistics of Lightning Discharge Currents and ELF and VLF Radio Noise. J. Geophys. Res., Vol. 72, No. 11, pp. 2943-2953, 1 Jun 1967. DAS F col.

...The received noise is considered as a result of integrating several atmospherics during the response time of the receiver. The probability distributions of this noise and of current in the lightning flashes are related by a twofold Hankel transform. The measured amplitude distribution of the received noise is inversely proportional to the squared amplitudes for very large signals, and the derived distributions of the effective source current exhibit a similar behavior. The large-amplitude source currents are associated with return strokes of lightning discharges. Their statistics exhibit such a behavior if they are computed in the presence of the more frequent, lower amplitude K pulses and if the velocity dependence of large-amplitude strokes is taken into consideration. (Author)

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73. Golde, R.H. Lightning Conductor. Franklin Inst., Phila., Journal, 283(6):451-477, figs, refs, eqs, Jun 1967. DLC T.58.

...The contents of this paper consist of the following considerations of lightning conductors including the function of the lightning conductor, the long spark discharge, the final stage of a lightning stroke to the ground, the striking distance of a lightning discharge, the range of attraction of a lightning conductor and the space protected by it, and practical aspects of the lightning protection of structures, including the roof conductor system, down conductors, grounding systems, and protective range. It is concluded that in order to avoid side flashing in the ground, bonding is essential between the lightning protective Earth electrode and any adjacent buried metal pipes or cables, and that vertical finials can be replaced by horizontal roof conductors which should be so arranged as to cover all sharp edges of the roof structure. (ILD & PS)

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74. Hart, J.E. VLF Radiation from Multiple Stroke Lightning. J. Atmospheric Terrest. Phys. Oxford, 29(8):1011-1014, Aug 1967. DAS M(05) J86a.

...The frequency-amplitude spectra of atmospherics generated by return stroke currents in multiple stroke lightning have been obtained using an electronic transient analyzer. These spectra are compared to those suggested by theoretical considerations. The results support the predicted spectrum shift to the low frequencies for second return strokes. (Author)

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75. Horner, F. Analysis of Data from Lightning-Flash Counters. Institution of Electrical Engineers, London, Proceedings, 114(7):916-923, Figs, refs, eqs. Jul 1967. DLC TK1.I4.

## 75. (cont)

...Data from observations with lightning-flash counters in England and Singapore show the diurnal and seasonal variations, and comparisons are made with established observations of thunderstorm days. (Author)

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76. Kourtz, P.H. Lightning Behaviour and Lightning Fires in Canadian Forests, Ottawa 1967. Canada. Dept. of Forestry and Rural Development. Forestry Branch. Departmental publication no.1179. 33 p. 5 figs, 10 tables. DAS M:634.9 C212pu no.1179.

...The behaviour and occurrence of lightning and lightning-caused forest fires in the years 1960-1963 were studied on the basis of data on 3,615 lightning-caused forest fires. A review of literature indicated that the tree species most frequently struck were the most abundant species having the most favourable characteristics to attract lightning. The nature of the damage depends on the dielectric properties of the tree and on lightning-flash energy. (Author)

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77. Loeb, Leonard B. Contributions to the Mechanisms of the Lightning Stroke. Monthly Weather Rev., Wash., D.C., 95(12):827-834, Dec 1967, refs. DAS M(05) v587m.

...Author's earlier paper on the mechanism of the cloud to ground lightning stroke was based on classical observational data. The report on the last 10 yrs observations of strokes from Monte San Salvatore by Berger and Vogelsanger using improved instrumentation calls for a reassessment of the theory and makes possible a tentative extension to the intracloud stroke mechanisms. The salient new findings from Monte San Salvatore are summarized. The theory of the author is considered in terms of the observations. The theory in general is confirmed by these observations and certain more hypothetical conjectures are confirmed by the greater detail available in the new observations. No serious contradictions appear requiring alteration of the theory. Probably the most significant new observations deal with the nature of the positive leader strokes which had not previously been observed in detail. These, together with the very important 1964 observation of Brook and Kitagawa on intracloud strokes, furnish the basis for a tentative analysis of the mechanisms active, (Author)

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78. Newman, M.M., Stahmann, J.R., and Robb, J.D. Airflow Velocity Effects on Lightning Ignition of Aircraft Fuel Vent Efflux. Lightning and Transients Research Inst, Minneapolis, Minn. Final Rept. FAA-ADS-67-9. July 1967. 37 p. AD 660206.

...Studies of the effects of airflow, at aircraft holding velocities up to 250 knots, over the surface of an aircraft wingtip containing a recessed fuel vent showed that the probability of lightning ignition of the fuel vent efflux was greatly reduced by the airflow. From almost certain ignition with no airflow and the optimum fuel flow rate and mixture obtainable, the ignition frequency dropped to one in 34 shots with 50 knots airflow, one in 31 shots at 90 knots, none in 200 shots at 200 knots and none in 10 shots at 250 knots. Streamering at the recessed fuel vent

78. (cont)

studied, due to a five megavolt surge, did not produce ignition, even with no airflow. (Fr. Author's Abs.)

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79. Newman, M.M., Stahmann, J.R., and Robb, J.D. Experimental Study of Triggered Natural Lightning Discharges. Lightning and Transients Research Inst. Minneapolis, Minn. Final Rept. FAA. Mar 1967. 59 p. refs. AD 661827.

...Studies of the natural lightning discharge channel have been continued using a triggering technique during which seventeen strokes were triggered out of twenty-three attempts. The discharges were triggered by firing a rocket carrying a fine wire to an altitude of about 100 to 400 meters when electric field meters indicated a discharge was probable. The studies showed clearly in the Fastax photographs, the current oscillograms, and in the still photographs, the existence of a low current continuing component lasting up to 0.8 seconds following nearly every initial high current stroke. High current restrikes were found after nearly every stroke with as many as eleven restrikes to a single lightning discharge. Blast pressure measurements showed only slightly higher peak pressures than measured previously from triggered natural lightning discharge. This is of interest in relation to possible structural damage to aircraft and also in relation to shock wave effects on flame propagation in aircraft fuel vents. High speed motion pictures of the discharge clearly showed the snake-like motion of the channel which is of interest in evaluation of stroke sweeping effects near aircraft. (Author)

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80. Orville, R.E. Ozone Production During Thunderstorms, Measured by the Absorption of Ultraviolet Radiation from Lightning. J. Geophys. Res. Vol. 72, No. 14. pp. 3557-3561. Jul 1967. DAS P col.

...The only spectrum of a single lightning flash containing the short-wave ozone absorption cutoff has been obtained. An analysis of this absorption in the 2850-A region indicates that a few tenths of a millimeter (0.01-0.05 cm) of ozone existed between the slitless spectrograph and the flash occurring at a distance of 0.85 km. This value is one order of magnitude greater than the clear air value. An experiment is suggested to determine whether the ozone exists in a mantle around the lightning channel and, hence, is produced by lightning, or whether it is evenly distributed in the intervening path and, hence, is produced by thunderstorm-induced corona. (Author)

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81. Peterson, Robert R. Transmitting Radar Echo Locations to Local Fire Control Agencies for Lightning Fire Detection. Western Region Tech. Memo. No. 20. Salt Lake City, Mar 1967. DAS M(055) v587wet No.20.

...In Forest Service Region I, over 70% of the fires are started by lightning, with an average of about 1000 lightning fire starts per season. Forest Service Region I is composed of 16 National Forests in western Mont., northern Idaho, and northeastern Wash., with Regional Hqs., at Missoula, Mont. (Author)

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82. Ramsey, B.L. Montana LASA Lightning Activity for 1966. Philco-Ford Corporation, Educational & Technical Services Division, May 22, 1967. Sections separately paged. 45 p. figs, table. DAS M(055) P545mo. AD 658177.

...Reports on lightning activity within the Montana LASA during 1966, with comparisons to 1965 data. Included are observations of lightning activity, damage to LASA equipment, a description of present lightning protection circuitry, and discussions of the lightning counter equipment. LASA equipment damages were considerably reduced. Present lightning protection configurations are delineated. (ES)

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83. Rao, Manoranjan. (Comments on) His: Corona Currents After the Return Stroke and the Emission of ELF Waves in a Lightning Flash to Earth. Radio Science, Wash. D.C., 2(11):1394, Nov 1967, fig, eqns, original appeared as 18.7-603, met. abs. DLC QC 851 .R3.

...Presents the correction factor suggested by J.R. Wait (1967 private communication) to apply to the author's previously published 1967 equation. A graph of the corrected and uncorrected ELF spectra shows that at the lower end of the ELF band the difference between the corrected and uncorrected spectra is very great. (Fr. Author's Abs.)

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84. Strommen, Norton D. Lightning Fatalities and Injuries in Michigan, 1897-1966. Wash. D.C., Environmental Science Services Administration in cooperation with Michigan Dept of Agriculture, Michigan Weather Service, etc., Oct 1967. 12 p. figs, refs. DAS (M94.221 S921L1).

...The electrical basis of lightning formation is described briefly and the incidence of deaths due to lightning for 1897-1966 is discussed. During this period a total of 157 deaths were caused by lightning; this is a minimum figure. Deaths and injuries caused by lightning have occurred in the period Mar through Oct; Jun and Jul accounted for over 50% of the total. The period 1897-1906 accounted for more than twice as many deaths as any other decade. Histograms giving the lightning casualties by months and by decades, and lightning deaths for the period 1897-1966; and a map showing number of deaths and injuries by county for this period are given. Suggestions for avoiding lightning injury out-of-doors are listed. (ILD)

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85. Teletov, G.S. Ball Lightning "Priroda," No. 9, 1966. Section titled 'Hypotheses,' pp. 84-92, trans. by D. Mohr, et al. n.p. Apr 1967. 21 p. 5 figs, AD 651431.

...This article opens a discussion of the nature of ball lightning. The editors consider it of considerable interest to review the properties of ball lightning and the hypotheses that have been advanced to explain them. The author's own hypothesis assumes the existence of an unusual state of matter still being studied by modern science. As the author himself notes, one must resort to such hypotheses only when the more customary explanations have been exhausted. In a later issue of this journal an article will be published setting forth another hypothesis closer to the usual concepts. (Editor's Abs)

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86. Wagner, C.F. Lightning and Transmission Lines. Franklin Inst., Phila., Journal, 283(6):558-594, Jun 1967, figs, refs, eqs. DLC T1.F8.

...On the basis of a review of existing knowledge of lightning strokes the author discusses the characteristics of the first component, the subsequent components, stroke current probability and stroke density; surge impedance and potential of stroke, the shielding of transmission lines, direct stroke theory of line protection, indirect strokes, prestrike theory, the difficulties of computations, and pipeline gaps. (ILD)

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87. Zegel, Ferdinand H. Lightning Deaths in the United States: A Seven-Year Survey from 1959-1965. Weatherwise, Vol. 20, No. 4, Aug 1967, pp. 168-173, 179. 9 refs, 3 figs, 4 tables. DAS M(05) W362.

...This survey investigates the distribution of lightning deaths in the U.S. Comparisons are made for the factors of sex, time, and age. The tables list monthly averages for deaths by lightning. Annual totals are categorized by situation (under trees, on water, etc). Also included is a list of annual property damage caused by lightning. (DLB)

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88. Ayer, Harold S. Probability Forecasting: A Problem Analysis with Reference to the Portland Fire-Weather District. U.S. Weather Bureau, Western Region Technical Memorandum No. 32, July 1968, 10 p. Figs, charts, refs. DAS M(055) U587 wet.

...In view of a probable high acceptance rate by forestry and fire control groups of probability forecasting, the objective of bringing all probability statements toward 0 and 100% is established. In arranging a forecasting service, user needs, forecasters' capabilities, and basic physical differences in behavior of weather types must be considered. The spatial patterns occurring in lightning storm situations differ from those of rain storms. (JPD)

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89. Barasch, Guy E. The 1965 ARPA-AEC Joint Lightning Study at Los Alamos. Vol. II, Univ. of California, Los Alamos Scientific Laboratory, LA-3755, TID-4500, Feb 1968, 17 p. 18 figs, 10 refs, AD 665141. See also Vol. I, AD 663136.

...This is the second of 2 reports on the optical emission characteristics of lightning, investigated at Los Alamos during the summer of 1965. Because lightning pulses are capable of producing false alarms in nuclear-explosion-detection systems that rely on optical detection of the burst of air fluorescence excited directly or indirectly by an explosion, a lightning study was conducted to find optimum methods to discriminate against such false alarms. (Author)



90. Barry, J. Dale. Laboratory Ball Lightning. J. Atmospheric & Terrest. Phys. Oxford, 30(2):313-317, Feb 1968. Figs, refs. DAS M(05) J86a.

...A mechanism for the formation of ball lightning is discussed. It is suggested that the presence of a low density of simple hydrocarbons in the atmosphere, coupled with an atmospheric electrical discharge, may be sufficient to form the phenomenon. A laboratory experiment is described in which a ball of fire was formed. The phenomenon appeared to possess many properties of natural ball lightning, including existence for a finite time without an external energy source. (Author)

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91. Battan, Louis J. Some Problems in Changing the Weather. Weatherwise, Boston, 21(3):102-105; 120, Jun 1968. Figs, photos. DAS M(05) W362.

...Reviews the major problem areas in weather modification, with emphasis on cloud seeding techniques by means of dry ice, silver iodide, and lead iodide. It is conceded that such seeding does dissipate "supercooled" clouds and fogs, but that the degree of effectiveness of such techniques in increasing or redistributing precipitation has not yet been established. Efforts to suppress hail are discussed. The Soviet techniques in the Caucasus are cited. Claims of successful efforts to suppress lightning by very heavy cloud seeding with AgI are said to be premature, while cloud seeding in severe storms has led to inconclusive results due to lack of knowledge of the natural mechanisms of such atmospheric systems. (ALS)

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92. Blevins, L.L., et al. Visual Observations of Lightning in Some Great Plains Hailstorms. Weather, Vol. XXIII, No. 5, May 1968, pp. 192-194, 6 refs, 3 figs. DAS M(05) R889w.

...Visual observations of lightning strokes were made during the 1966 Northeastern Colorado Hail Project. A mobile observer would attempt to place himself in front of a thunderstorm by means of visual and/or radar information via 2-way radio. While ahead of the thunderstorm, he would make lightning counts. When the precipitation reached him he would either move around within the precipitation looking for hail or would attempt to place himself ahead of the thunderstorm again. The observer attempted to restrict his counts to one individual thunderstorm. In general, lightning counts were taken in 3-min intervals over various portions of the life cycle of the storms. Distinctions were made between cloud-to-cloud and cloud-to-ground lightning strokes. Hailers were defined as thunderstorms which produced hailstones larger than 1/4 in. diameter within  $\pm 15$  min of the lightning count. Hail occurrence was determined by personal observations or by field survey. (Author)

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93. Bunn, C.C. Application of Electric Field Change Measurements to the Calibration of a Lightning Flash Counter. J. Geophys. Res., Vol. 73, No. 6, pp. 1907-1912, 10 refs, 12 figs, Mar 15, 1968. DAS P col.

...The input circuit of the lightning-flash counter adopted by Study Committee 8 of the Conference Internationale des Grands Reseaux Electriques is intended to have a threshold of 5 v/m and, consequently, also has a calculable response to ramp changes in the electric field. It is shown that, for ramps of sufficient duration, either a positive ramp or a

93. (cont)

truncated negative ramp of slope  $6000 \text{ (v/m) sec}^{-1}$  will cause the counter to register. Electric field changes caused by identified lightning flashes have been analyzed in terms of steps and ramps, and magnitude distributions of these have been obtained. The distributions were used in conjunction with the threshold of the counter to steps and ramps, and the fraction of flashes that cause the counter to register was calculated for various distances between counter and flash, using the inverse cube law of variation of field change with distance. The effective ranges for ground and cloud flashes were calculated to be 30 and 20 km, respectively. The method described is applicable to any simple flash counter using detection of electric field changes. (Author)

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94. Cobb, William E. et al. A Note on Lightning Strikes to Aircraft. Monthly Weather Rev. Vol. 96, No. 11, Nov 1968, pp. 807-808. DAS M(05) v587m.

...A DC-6 research aircraft was struck by lightning on 3 occasions during a thunderstorm research project at Flagstaff, Ariz., in Jul 1967. Electric fields and meteorological parameters were measured and recorded. Similar conditions existed at the time of the lightning strikes. Each event occurred in a dissipating Cb, near the freezing level and in a region containing both ice and water. Corona discharge from the aircraft occurred prior to each strike. The possibility exists that one or more of the lightning strikes were triggered by the aircraft. (Author)

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95. Connor, T. Robert. Stroke and Space Resolved Slit Spectra of Lightning. Los Alamos Scientific Lab. N. Mex., LA-3754-ADD, 37 p. refs, Aug 1968. AD 672916.

...Twenty-four stroke-resolved slit spectra of lightning taken in 1966 are presented, one of which is also the first space-resolved slit spectrum of a return stroke. These split spectra unambiguously show that the lightning return-stroke channel is a strong continuum source and that the continuum observed in the slitless spectra in 1965 is real and not the result of line radiation scattered from natural backgrounds such as clouds, haze, or rain. (Author)

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96. Dawson, G.A. et al. Discussion of a Paper "Pressure from a Lightning Stroke," J. Geophys. Res., Vol. 73, No. 20, Oct 15, 1968, pp. 6595-6597, refs. DAS P col.

...Suggests that 1) the conclusions drawn by Hill and Robb (1968) are not a logical consequence of their results, 2) there is apparently no need to question the previous interpretation of the spectroscopic data, and 3) the pressure pulses observed by them are of about the magnitude to be expected under the conditions of the experiment. The pressure data of Hill and Robb are consistent with the theory of Few, et al (1967) and Brode (1956), strengthening the view that the equilibrium time is short. (ES)

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97. Evenson, K.M. Ball Lightning Research at Highland Lookout, Montana. Space Sciences Dept. Douglas Aircraft Co, Inc., Santa Monica, Calif. Report No. DAC-60941. 18 p. Jan 1968. AD 664366.

...The existence of ball lightning has only recently begun to be accepted by the scientific community, although many sightings have been reported over the past 200 years. In this century, many hypotheses have been suggested to explain the observed properties of ball lightning. In the past two years, some attempts have been made to produce 'ball lightning' in the laboratory. A few of these attempts have been partially successful, one being that of J.D. Barry of UCLA who recently produced what appears to be a form of ball lightning at atmospheric pressure (to be published). In order to determine the nature and properties of ball lightning, it was decided that an attempt must be made to obtain physical data in the field. This report presents the results of a site survey of a possible location where ball-lightning activity may be high enough to guarantee some success in making physical measurements. (Author)

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98. Hill, E.L. et al. Pressure Pulse from a Lightning Stroke. J. Geophys. Res. Vol. 73, No. 6, Mar 15, 1968, pp. 1883-1888, 26 refs. DAS P col.

...Measurements of pressure pulses from triggered lightning strokes show that they are not the result of strong mechanical shock waves of the type postulated by Abramson et al. as the explanation of channel growth in spark breakdown. Physical arguments, which are applicable also to natural lightning strokes, indicate that the rate of thermal heating in the channel is too slow to allow the development of the required strong ionizing shock front. (Author)

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99. Hill, Robert D. Analysis of Irregular Paths of Lightning Channels. J. Geophys. Res. Vol. 73, No. 6, pp. 1897-1906, 15 Mar 1968, AD 672307.

...The tortuosities of a number of lightning stroke channels have been measured by a method similar to that used for determining the scattering of the track of a nuclear particle. The distribution of the direction changes of sections of the channels are found to be Gaussian, and they appear to be characteristic of a noise variation of the channel direction. For cloud-to-ground strokes the magnitude of the noise appears to be largely independent either of section length or total length of channel or of the particular locale of the stroke. (Author)

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100. Hughes, H.G. Lightning Discharge Characteristics Determined from Extremely Low-Frequency Atmospherics. Naval Electronics Lab Center for Command Control and Communications, San Diego, Calif. Rept No. NELC-1540, Res. Rept. Jul 67-Feb 68, 23 p. 29 Feb 1968, AD 671996.

...The physical description of a median lightning flash is of practical interest in the statistical evaluation of the global electromagnetic noise spectrum and its effects upon communication systems. A technique for locating and investigating the 'fine structure' of individual lightning discharges occurring several thousands of kilometers from a single receiving station is described. The method employs the simultaneous measurement of the vertical and horizontal components of 'slow tail'

## 100. (cont)

atmospheric waveforms. Particular example of 'slow tail' waveforms with different characteristics received from lightning discharges occurring simultaneously in widely separated localities are presented. The mean amplitude spectra of the waveforms emanating from the two storm areas are used to calculate the mean source current moment spectra of the waveform sources using zero-order mode theory. The calculated spectra are then compared with data of other workers who employed different measurement techniques. Plans for future measurements necessary to refine the technique are also discussed. (Author)

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101. Kleimenova, Z.P. O sootvetstvií mezhdú global'nymi i lokal'nymi kharakteristikami groz. [Conformity between global and local thunderstorm characteristics.] Leningrad. Glavnaia Geofizicheskaya Observatoriya, Trudy, No. 225:50-54, 1968. Refs. eqs. Russian summary p. 139. DAS M(055) V581tg.

...Calculations showed that instrumental data on the number of local thunderstorm discharges do not contradict the universally adopted value of the mean number of lightning strokes on the entire Earth (100 discharges/sec). During the past 40 yrs, it was not possible to define this quantity more accurately; the situation may be changed only with an improved observation method for distant thunderstorm foci. In solving a number of problems, it is necessary to make use of the relative evaluation of the world thunderstorm foci. The calculations lead to the conclusion that these foci are responsible for  $< \frac{1}{2}$  of the number of discharges observed over the entire Earth. Therefore, consideration of the general background of thunderstorm activity is of prime importance. (Author)

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102. Kofoid, Melvin J. Lightning Discharge Heating of Titanium Aircraft Skins. Boeing Scientific Research Labs., Seattle, Wash., Plasma Physics Lab. Sep 1968, 65 p. refs. AD 677352.

...Because of the low thermal and electrical conductivities of titanium (Ti) metal there is serious concern as to the temperature to which skin metal may rise at the terminal of a lightning discharge to an aircraft. Of particular interest is the maximum anticipated temperature of the back side, or interior surface when a single sheet constitutes the outer wall of a fuel tank. (Author)

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103. Krider, E.P. et al. Peak Power and Energy Dissipation in a Single-Stroke Lightning Flash. J. Geophys. Res. 73(10):3335-3339. May 15, 1968. Figs, refs, DAS P col.

...The peak radiant power and the total radiant energy emitted within a given spectral region by a single-stroke lightning flash are compared with those given off by a long spark whose electrical power and energy inputs are known with fair accuracy. An average power input per unit length of  $7.8 \times 10^8$  w/m, at the instant of peak radiant emission from the entire channel, and an average energy per unit length of  $2.3 \times 10^5$  J/m were obtained. The peak power value represents the most reliable

## 103. (cont)

determination of that parameter for lightning to date, and the energy value is in good agreement with other estimates. (ES)

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104. Leeb, Leonard B. Confirmation and Extension of a Proposed Mechanism of the Stepped Leader Lightning Stroke. J. Geophys. Res. 73(16):5813-5817, Sep 15, 1968. Refs. DAS P col.

...The postulated space wave of potential gradient, originating in an asymmetrical velocity of advance of positive and negative streamers and resulting from encounters of positive streamer tips with negative charge elements, has now been verified by WAGNER in uniform field breakdown in the laboratory. This space wave constitutes the fast bright step that reactivates the pilot leader advance. Possible reflection at the end of the pilot streamer advance may account for the illumination of earlier steps reported by BERGER and VOGELSANGER and for resonances leading to step uniformity. Recent work by KOPPITZ and by THOLL concern the rapid thermalization of the arc channels estimated by UMAN. They account for the millimeter-diameter core photographed by ORVILLE and theoretically inferred by UMAN, which also explains the streaks in time-resolved stroke photographs. (Author)

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105. Mackerras, D. A Comparison of Discharge Processes in Cloud and Ground Lightning Flashes. J. Geophys. Res. Vol. 73, No. 4, pp. 1175-1183, 15 Feb 1968. DAS P col.

...The electric field changes caused by identified cloud and ground lightning flashes have been analyzed in terms of their more conspicuous features, in particular, duration, over-all magnitude, number and size of steps, and presence and maximum slope of ramps. Plots of field change against distance showed reasonable agreement with the inverse cube law, which has been used for normalizing field changes of flashes at various distances between 3 and 20 km. Statistical distributions of the measurements were used as a basis for comparing the field changes of ground and cloud flashes; it was observed that impulsive discharges occurred in both but were more frequent and caused larger field changes in ground flashes than in cloud flashes. Furthermore, flashes in the upper part of the thundercloud involved fewer impulsive discharges than cloud flashes about cloud base level, suggesting that height in the thundercloud influences the mode of discharge. (Author)

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106. Nelson, L.N. Magnetographic Measurements of Charge Transfer in the Lightning Flash. J. Geophys. Res. 73(19):5967-5972, Sep 15, 1968. Figs, tables, refs, eqs. DAS P col.

...Charge transfer in the cloud-to-ground lightning flash was calculated from measurements of magnetic field changes recorded by a rapid-run torsion magnetometer. The magnetometer was calibrated and found to comply with theory for its response. Seventeen flashes were located by stereographic photography during 5 nighttime storms in the summer of 1963. The charge transfer for these flashes ranged from 355 to 19 coulombs with a mean of 199 coulombs. A detection bias in favor of flashes

## 106. (cont)

transferring large amounts of charge as well as systematic underestimates of charge transfer are present in the system used. An increase in the accepted value of maximum charge transfer is indicated, but these data are insufficient to justify an increase in the accepted average value. (Author)

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107. Oetzel, George N. Computation of the Diameter of a Lightning Return Stroke. J. Geophys. Res. Vol. 73, No. 6, Mar 15, 1968, pp. 1889-1896, 19 refs, 6 figs. DAS P col.

...The diameter of lightning return strokes has been measured by a number of different methods, with little consistency in the results. In this research, the diameter of the return stroke is computed according to simple electrical circuit models based on other experimental results. The computed diameters for different situations may help to clear up the discrepancies between the experimental diameter measurements. Two models are considered. The first is a lumped, resonant circuit; the second is a charged transmission line. Both models give current waveforms that closely approximate the current actually measured at the base of lightning strokes. In both cases, the diameter computed is the same. The diameter of a first return stroke is found to lie in the range 1-4 cm. Subsequent return strokes are smaller, with diameters in the range 0.2-0.5 cm. In many cases, strokes to towers have shown evidence of the smaller strokes occurring alone. These are explained as strokes initiated by an upward leader. (Author)

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108. Oetzel, George N., et al. The Radio Emissions from Close Lightning. Stanford Res. Inst., Scientific Note-10, Contract Nonr-4099(00). Feb 1968, 46 p. AD 666711.

...This survey considers the frequency range from below 1 kHz to above 10 MHz. At all frequencies the peak amplitude of the noise accompanying a single flash is examined. The structure and amplitude distribution of the separate pulses occurring within a complete discharge are investigated with particular reference to frequencies exceeding some 3 MHz. Among special topics discussed are the excitation of Schumann resonances, the generation of slow tail signals at frequencies less than 1 kHz, and the production of pulses at VLF (3-30 kHz) by return-strokes and other features of a lightning flash. Conclusions and recommendations for further work are given. (Author)

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109. Orville, Richard E. High-Speed Time-Resolved Spectroscopic Study of the Lightning Return Stroke, Pt. 1, A Quantitative Analysis. J. Atmospheric Sci, Boston, 25(5):827-838, Sep 1968. Figs, refs. Also: Pt. 2, A Quantitative Analysis. Ibid. pp. 839-851. Figs, tables, refs, eqs. Also: Pt. 3, A Time-Dependent Model. Ibid. pp. 852-856. Figs, refs. DLC QC 851.A283.

...The first time-resolved spectra of return strokes between the cloud and ground have been obtained. During the summers of 1965 and 1966 22 spectra were obtained at the Inst. of Atmospheric Physics, Tucson, Ariz. The spectra were recorded with 2 high-speed streaking cameras converted

109. (cont)

to slitless spectrographs. Most of the data were obtained with a Beckman and Whitley high-speed camera. A 200-mm objective lens was used to focus for the return stroke on a 0.5-mm horizontal slit. Thus, a 10-m section of the lightning channel was isolated for a discharge occurring at a distance of 4 km. Data have been obtained with a time resolution 2-5  $\mu$  sec. All spectra have been recorded on film calibrated for intensity and wavelength with a xenon source of known relative spectral emittance. The recorded time sequence of spectral emissions from a section of the lightning channel is: 1) line radiation from singly ionized atoms, 2) continuum, and 3) line radiation from neutral atoms. A flash has been recorded composed of at least 5 strokes. Two types of strokes are observed in this flash. The first type is characterized by intense short-lived emissions from singly ionized nitrogen atoms (N II) and a long lasting H-alpha emission. It is shown that, if the number density of a particular emitting species is known, the relative channel radius within which the particular radiators are contained can be calculated as a function of time. The salient characteristics of the model return-stroke are discussed and related to spectral observations. (Author)

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110. Orville, Richard E. Photograph of a Close Lightning Flash. Science, Wash. D.C., 162(3854):666-667, Nov 8, 1968. Photos, refs. DAS P col.

...A lightning flash was photographed striking a European ash tree at a distance of 60 m. The tree sustained no external physical damage. The probability of obtaining this photograph is estimated to be  $10^{-3}$ , or once in 1000 years. (Author)

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111. Orville, R.E. Spectrum of the Lightning Stepped Leader. J. Geophys. Res. Vol. 73, No. 22, 15 Nov 1968, pp. 6999-7008, 25 refs, 4 figs, table. DAS P col.

...A high-speed camera was modified to a slitless spectrograph to record the spectral emissions from a section of the lightning channel. Spectral emissions from a 2-meter section of a negatively-charged stepped-leader channel are recorded. Stepped-leader emissions for various wavelengths are characterized by different, singly-ionized atoms. These leader-channel emissions vary as a function of time as the stepped-leader progresses toward the ground. A temp. of 30,000 degrees K is calculated for the leader step. The diameter of the leader channel defined by the N II spectral emissions is less than 0.5 meter. (Author)

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112. Petterson, B.J. Measurements of Lightning Strikes to Aircraft. Final report, Contract FA65WAI-94, FA66NF-AP-12, by B.J. Petterson and W.R. Wood, Sandia Lab., Albuquerque, N.M. Wash., Dept. of Transportation, Federal Aviation Admin., Aircraft Development Service, Engineering and Safety Div., 1968. 146 p. (Report DS-68-1) AD 669124. DAS M(651) U5833re DS-68-1.

...Primary interest was in the effect of lightning on nuclear weapons and on aircraft and missile wiring. A description of the test instru-

## 112. (cont)

mentation, its installation in the aircraft, and an analysis of the results obtained is given. Flights were made into thunderstorms off the coast of Florida. Strikes were photographed and recorded, and the information was later analyzed. Although certain trends in effects were noted, no specific conclusions have been drawn. Further tests will be necessary to permit definition and reproduction of the lightning current signature. (Author)

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113. Pierce, Edward T. The Counting of Lightning Flashes. Stanford Research Institute, Special Technical Rept No. 49, June 1968, 97 p. AD-682023.

...In this study ERA and CCIR types of counters are discussed. General procedures for lightning-flash counters usage are presented. Results from 2 Thai sites are compared with data for Singapore. (DLB)

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114. Semenov, K.A. Some Results of Tests on Thunderstorm Detectors with a Small Range of Coverage. [Nekotorye rezul'taty ispytanií grozoregistrátorov s malym radiusom deistviia], Transl. by AMS into English from Tr. Gl. Geofiz. Observ. (Leningrad), No. 157, 1964, pp. 59-67, AFCRL Contract AF 19(628)-3880, TR 571, Bedford, Mass. Jan 1968, 17 p., refs. AD 667417.

...Experimental data on thunderstorm discharges recorded within a radius of 10-20 km by instruments with a variety of designs are compared and analyzed in the present paper. (Author)

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115. Timofeev, N.T. Grozovye razlady i ikh kolichestvennaia kharakteristika v nekotorykh gornykh raionakh proektirovaniia trass DEL Nurekskaya GES-Tashkent. [Lightning discharges and their quantitative characteristics in some mountain areas near the planned power line between the Nurek-skaya Hydroelectric Station and Tashkent.] Leningrad. Glavnaia Geofizicheskaya Observatoriia, Trudy, No. 225:128-131, 1968. Tables, refs. Russian summary p. 143. DAS P col.

...The author presents data from visual observations of the monthly recurrence of various types of thunderstorm discharges during Feb-Jun, 1963-1965 in low- and high-altitude regions and 2) the thunderstorm danger in these regions during this period. On the average, the discharges of the cloud-ground type amounted to 11% of the entire number of discharges on mountains and to 2% in valleys. The thunderstorm danger/km<sup>2</sup>/one thunderstorm day was, on the average, 0.01 on the ridge and 0.003 in the valley. Between Aug 1965 and Jul 1966, thunderstorm recorders (type PRG-1), with effective action radius of 10 km, were installed in the indicated regions. Based on the recorded data, values of thunderstorm danger were higher by one order of magnitude than indicated by data obtained from visual observations. (Author - Transl. PVT)

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116. Uman, M.A. Some Comments on Ball Lightning. J. Atmospheric & Terrest. Phys., Vol. 30, No. 6, Oxford, Jun 1968, pp. 1245-1246. DAS M(05) J86a.

...An account is presented of ball lightning entering a metallic aircraft and leaving without causing damage. It was concluded that this ball lightning was of a type with an internal energy source. The possibility that more than 1 type of ball lightning exists is presented. Theoretical models are proposed for the phenomenon, without solving the problem. (SN)

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117. Uman, Martin A. et al. Time Interval between Lightning Strokes and the Initiation of Dart Leaders. J. Geophys. Res., Vol. 73, No. 2, Jan 15, 1968, pp. 497-506, 29 refs, 4 figs, table. DAS P col.

...The temperature decay of a lightning channel during the interstroke period is determined theoretically. It is shown that, in the absence of input energy to the channel, the channel temperature will decay sufficiently slowly so that conditions conducive to the initiation and propagation of a dart leader will exist in the channel after a typical interstroke period of 40 msec. Thus, it would appear unnecessary to invoke the special mechanisms suggested by Brook, et al, and by Loeb to explain the 'long' interstroke period. The calculations indicate that the lightning channel radius during the latter stages of a lightning stroke is of the order of centimeters. A mechanism is suggested to explain the phenomenon of bead lightning and to account for the observed long-lasting luminosity occurring at certain points on the normal discharge channel. (Author)

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118. Weickmann, H.K. Program on Weather Modification of the Environmental Science Services Administration (ESSA), Pt. 3, Augmentation of Continuous Rain and Lightning Suppression. Idojaras, Budapest, 72(4):219-232. Jul/Aug 1968. Figs, photos, tables, eqs. DAS M(05) I21.

...The discussion of the augmentation of continuous rain is concerned mainly with extratropical cyclones. It includes an examination of the principles underlying the designing of a randomized rain augmentation program, the numerical model for determining whether an increase in the number of precipitation particles will increase precipitation developed by WEXLER and ATLAS, and an example of the calculation of actual increase in precipitation by cloud seeding. The redistribution of precipitation is examined on the basis of an analysis of the energy of a storm passing over the Great Lakes. The modification of colloidal stability within clouds by seeding with condensation nuclei is discussed on the basis of a review of SQUIRES and TWOMEY's work on the seeding of maritime clouds with a mixture of chlorosulphuric acid and the work of GILLESPIE and JOHNSON on warm fog dissipation. The concept and theory of lightning suppression are outlined with the aid of relevant equations. Some studies of inadvertent modification such as produced by air pollution are discussed, with particular reference to the atmospheric increase in CO<sub>2</sub> as measured at the Mauna Loa Obs. and the possible effect of CO<sub>2</sub> increase on the Earth's surface temperature. (ILD)

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1969

119. Bhartendu. Audio Frequency Pressure Variations from Lightning Discharges. J. Atmospheric & Terrest. Phys. Vol. 31, No. 5, 1969, pp. 743-747. DAS M(05) J86a.

...Audio frequency pressure variations associated with thunder were recorded. Spectral density estimates showed dominant maxima at 52 and 96 Hz. Measurements of sound pressure as a function of distance indicated that the wavefront of the thunder pressure wave was cylindrical.  
(Author)

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120. Gordon, W.F. Lightning Environments. Sandia Labs., Div., Rept. SCL-DR-69-40, Contract AF-(129-1)-789, Livermore, Calif., Apr 1969, 35 p. DAS M(051) v5833re.

...This report contains a basic description of lightning phenomena to assist system designers in (1) understanding the over-all environment, (2) identifying design strength and weaknesses from a susceptibility standpoint, (3) viewing potential design problems in proper perspective, and (4) logically deriving an evaluation program with which to determine system transfer functions and ultimately susceptibility. The information is applicable to both safety and reliability design considerations. Lightning environments discussed include direct strikes to earth-based objects, direct strike to airborne objects, and EMP from nearby strokes.  
(Author)

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121. Hill, R.D. Electromagnetic Radiation from Erratic Paths of Lightning Strokes. J. Geophys. Res., Vol. 74, No. 8, Apr 15, 1969, pp. 1922-1929. 4 refs, 6 figs, table. DAS P col.

...A possible source of low-frequency electromagnetic radiation from lightning is the tortuous path of the return-stroke current. A number of photographs of lightning channels have been measured, and their tortuous paths have been Fourier-analyzed. It has been found that the amplitudes of the component harmonic oscillations of the paths diminish approximately as the inverse  $3/2$  power of the oscillation frequency. (Author)

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122. Pierce, E.T. The Charge Transferred to Earth by a Lightning Flash. Stanford Research Inst., Menlo Park, Calif., Scientific Note No. 12, 5 p. Feb 1969. AD 685774.

...The paper shows that a strong correlation is present in the magnetometer results of Meese and Evans between the charge deduced as passing to earth in a lightning flash and the distance from the discharge at which the experimental records were obtained. Such a correlation should, of course, not exist. Its presence casts grave doubt on the conclusion of Meese and Evans that charges of several hundred coulombs often flow to ground during a lightning discharge. (Author)

123. Randjelovic, Jordan. Ball Lightning and Electromagnetic Radiation from Linear Lightning Discharges. Foreign Science Bulletin, ATD, Library of Congress, Vol. 5, No. 2, Feb 1969. 6 p. 5 refs, 2 figs. DLC Q1 F.6.

...P.L. Kapitaa's hypothesis that ball lightning phenomena are due to microwaves generated by lightning is reviewed. Results of an experimental study of the microwave radiation are presented, and the instrumentation used is briefly discussed. (ALS)

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124. Uman, Martin A. Ball Lightning. Final Report, Westinghouse Research Laboratories, Contract F 44620-68-C-0073, AFOSR 69-0782TR, Apr 1969, 8 p. 10 refs. AD 686094.

...A brief description of the characteristics of ball lightning is given. The results of calculations of the decay with time of the visible light output, the weight, and the temperature of heated spheres of (1) air, (2) air with trace amounts of sodium, (3) air-carbon mixtures, and (4) air-copper mixtures are discussed. (Fr. Author's Abs.)

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125. Uman, Martin A. Determination of Lightning Temperature. J. Geophys. Res., Vol. 74, No. 4, Feb 15, 1969, pp. 949-957, 23 refs, 1 table. DAS P col.

...The assumptions on return-stroke channel opacity, temperature profile, and energy-state distribution that have been used in lightning temperature calculations are examined. It is shown that the assumptions used are probably valid, except perhaps during the initial few micro-seconds of the discharge, and that a reasonable approximation to local thermodynamic equilibrium exists within the return-stroke channel. (Author)

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## THEMIS Project No. 129

Oklahoma State University. A Center for the Description of Environmental Conditions (THEMIS Project No. 129). Weather Phenomena, School of Electrical Engineering, Stillwater, Okla. Annual Report to Dept. of the Army, Electronics Command, WP 69-I-4 (plus addendum), 31 Oct 1968. Contract No. DAA807-68-C-0083. DAS M(051) 0414wp. WP 69-I-4.

The research work described in this annual report was sponsored by the Department of Defense under Project Themis. Oklahoma State University Themis Weather Phenomena Studies are administered under Contract No. DAA807-68-C-0083. This basic report covers the history of the program, objectives, rationale, implementation plans, data gathering, pattern recognition data analysis, etc. Addendum to the annual report contains the various technical reports. Authors and titles are listed below:

1. Shreve, E.L. Preliminary Survey of the Present State of Knowledge of Atmospheric Electricity. 12 p.
2. Milanes, E.J. Preliminary Survey of the Present State of Knowledge of Lightning. 16 p.
3. Robinson, W.G. Preliminary Survey of the Present State of Knowledge of the Spectra from Lightning-Produced Plasma. 42 p.
4. Shreve, E.L. Theoretical Derivation of Atmospheric Electrical Properties. 30 p.
5. Shreve, E.L. An Analysis of Charge Transport and Equilibrium in the Global Atmosphere. 148 p.

## TEXTBOOKS

A selected listing of textbooks containing general information on lightning either in its entirety or within certain chapters follows. Publishers are included for the convenience of the user.

American Meteorological Society, Severe Local Storms, Meteorological Monographs, Vol. 5, No. 27, Sep 1963, publ. by AMS, 45 Beacon St., Boston 8, Mass. 247 p.

Blüthgen, Joachim, Allgemeine Klimageographie, Walter De Gruyter & Co., Berlin 1966. 720 p. (In German).

Cade, C. Maxwell and Davis, Delphine, The Taming of the Thunderbolts, London, New York, Toronto (Abelard-Schuman), 1969. 176 p. Maps and illus.

Chalmers, J. Alan, Atmospheric Electricity, 2d Edition, Pergamon Press, Oxford, London, New York, etc. 1967. 515 p.

Coroniti, S.C. (ed), Problems of Atmospheric and Space Electricity, Elsevier Pub. Co., Amsterdam, London, New York, 1965. 616 p.

Critchfield, W.J., General Climatology, Prentice-Hall, Inc., Englewood Cliffs, New Jersey, Second Edition, 1966. 420 p.

Donn, W.L. Meteorology, McGraw-Hill Book Co., New York, 3d Edition, 1965. 484 p.

Hellman, Harold, Light and Electricity in the Atmosphere, New York, Holiday House, 1968. 223 p.

Humphreys, W.J. Physics of the Air, Dover Publications, Inc., New York, 1964, 676 p.

Imyanitov, I.M. and Chubarina, E.V. Electricity of the Free Atmosphere, Translated from Russian by Israel Program for Scientific Translations, published for NASA and NSF, Wash. D.C., 1967. 212 p.

Loeb, L.B. Electrical Coronas, Univ. of California Press, Berkeley, 1965. 694 p.

Malan, D.J. Physics of Lightning, The English Univ. Press, Ltd., London, 1963. 176 p.

Mason, B.J. Clouds, Rain, and Rainmaking, Cambridge Univ. Press, 1962. 145 p.

Mason, B.J. The Physics of Clouds, Oxford, at the Clarendon Press, London, 1957. 481 p.

Ordway, R.J. Earth Science, D. Van Nostrand Co., Inc., Princeton, N.J., Toronto, London, 1967. 705 p.

Schonland, Basil, The Flight of Thunderbolts, Clarendon Press, Oxford, 1964. 182 p.

Tverskoi, P.N. Physics of the Atmosphere, Translated from Russian by Israel Program for Scientific Translations, for NASA and NSF, Wash. D.C., 1965. 561 p.

November 1969

USAF ETAC TN 69-8

Man, Martin, A. Lightning, New York, McGraw-Hill Book Co., Inc., 1969. 264 p.  
(McGraw-Hill Advanced Physics Monograph Series.)

Viemeister, Peter E. The Lightning Book, Garden City, N.Y., Doubleday, 1961.  
316 p. 71 figs, 53 plates.

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<p>This bibliography contains 126 annotated references concerning lightning, generally as it occurs in the atmosphere. A subject index is included showing the numbered items pertaining to each subject breakdown. A number of pertinent textbooks are given in a separate listing.</p>		

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41

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## LIST OF USAF ETAC TECHNICAL NOTES

<u>Number</u>	<u>Title</u>	<u>Date</u>
68-1	List of Available Seminars (superseded, see ETAC TN 69-2) (AD-669078)	May 68
68-2	Meteorological Rocket Data and Predicting the Onset of the Southwest Monsoon over India and Southeast Asia (AD-669364)	May 68
68-3	Bibliographies of Climatic References and Climatic Maps for Selected Countries (AD-672769)	Jul 68
68-4	Climatological Bibliography of the South Atlantic Ocean Area Including Certain Coastal Countries (AD-683761)	Nov 68
69-1	Selected Climatological Bibliography for Thailand (AD-685716)	Mar 69
69-2	Listing of Available Seminars (AD-685719)	Mar 69
69-3	An Annotated Climatological Bibliography of Romania (AD-688259)	May 69
69-4	Radar-Computed Rainfall Compared with Observations from a Dense Network of Rain Gauges (AD-688434)	Jun 69
69-5	Tractionability Study for Laotian Panhandle (AD-691006)	Jul 69
69-6	An Annotated Climatological Bibliography of India (AD-691432)	Aug 69
69-7	A Selected Bibliography on the Climate of the Central American Countries (AD- )	Sep 69
69-8	A Selected Annotated Bibliography on Lightning (1964-1969) (AD- )	Nov 69